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DEPARTMENT OF DEFENSE LAND FALLOUT PREDICTION SYSTEM

Volume IV
ATMOSPHERIC TRANSPORT

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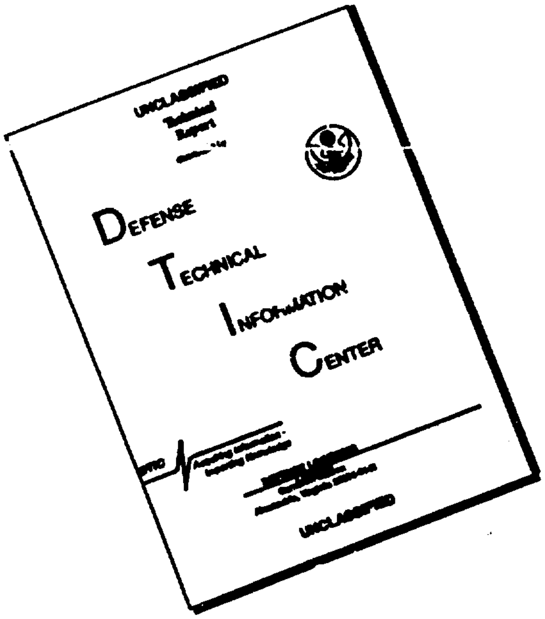

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For

DASA-1800-IV

DEPARTMENT OF DEFENSE LAND FALLOUT PREDICTION SYSTEM

Volume IV - Atmospheric Transport

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ABSTRACT

A collection of models developed to simulate atmospheric transport of local fallout from nuclear detonations is described. These models comprise the Transport Module of the Department of Defense Land Fallout Prediction System (acronym DELFIC). Details of the physical bases of the models as well as the Transport Module computer programs are presented. The programs provide for temporal and three-dimensional spatial variation of the wind field. Wind-field construction from input data can be accomplished by one of several preprogrammed methods that may be selected on the basis of the type and quantity of available data. Submodels for special local circulation systems can be superposed on the macrowind system. A capability to simulate highly variable topography is included. The computer programs are essentially open ended with regard to capacity for particle, wind field, and topography data.

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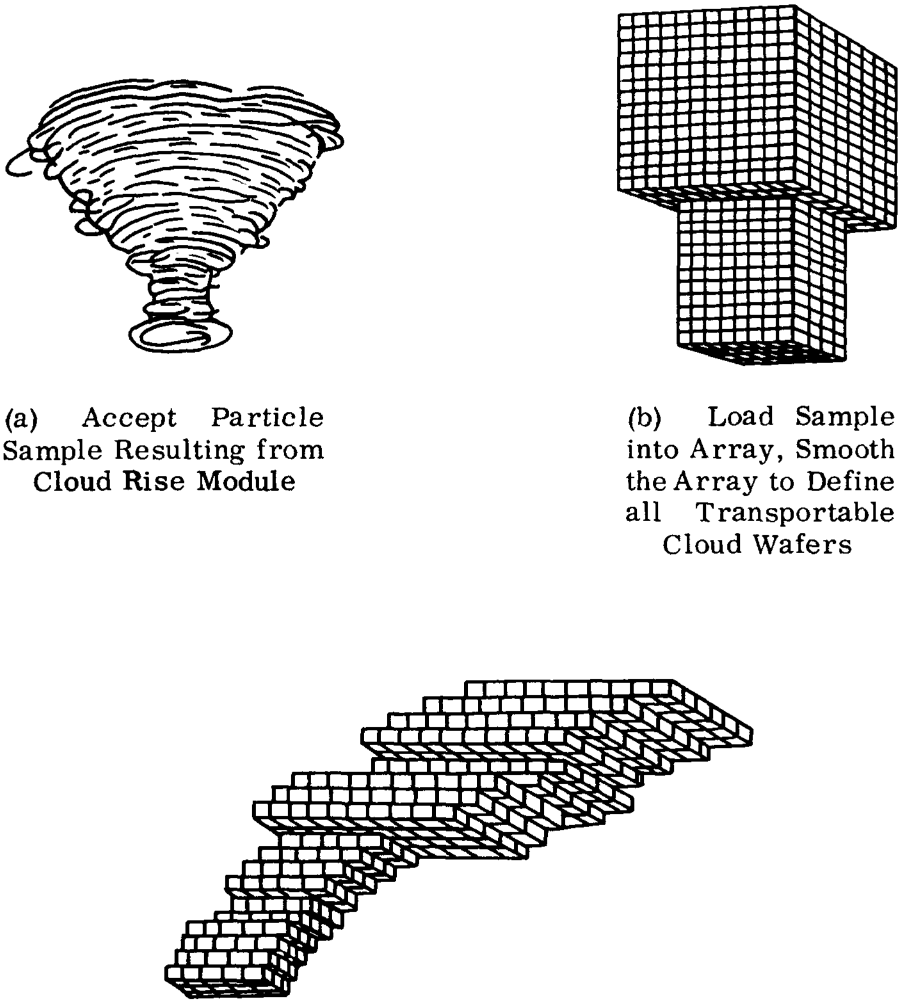
INTRODUCTION

The purpose of the Transport Module is to accept a list of fallout particle properties and positions at the end of the cloud rise and mathematically transport these particles through a temporally and spatially varying wind velocity field until they land on the ground or until the researcher's interests are otherwise satisfied. This module can be characterized by the terms atomistic, deterministic, and discrete. It is atomistic because the basic element of the module calculations is the fallout particle and, at least in concept, the end results of the model are based on the summation of the effects of individual particles. It is deterministic because the trajectories of individual particles falling through the atmosphere are uniquely determined by particle and atmospheric properties. It is discrete since the distributions of particles in space, particle size, and radioactivity are divided into discrete parts, the effects of which are associated with representative central particles. The macroscale atmospheric description used within the Transport Module is also discrete in that the atmospheric volume of interest during a given time period is divided into subvolumes (cells). Everywhere within a cell the atmospheric properties are considered to be uniform. Thus, the Transport Module is discrete in space, time, and particle size.

A set of fallout particles chosen as representative of the contents of cloud subdivisions is prepared by the Cloud Rise-Transport Interface program of the Cloud Rise Module. The generation of this input is described in detail in Volume III of this documentation; here we review only its essential highlights. Figure 1(a) depicts the particle cloud resulting from the rise and growth of the nuclear cloud before accounting for wind drift during cloud rise. A region of space that includes the cloud is subdivided, as shown in Figure 1(b), and a particle content is defined for each subdivision. In general, the contents of each cloud subdivision are unique. Each subdivision depicted in Figure 1(b) may be further subdivided into a large number of spatial subdivisions. Furthermore, each of these spatial subdivisions will be represented by a number of different central particles — one for each size class that is actually represented within the original cloud subdivision. Figure 1(c) depicts the location of the subdivisions representing a particular size range after the effect of wind drift during cloud rise has been accounted for.



(a) Accept Particle Sample Resulting from Cloud Rise Module

(b) Load Sample into Array, Smooth the Array to Define all Transportable Cloud Wafers

(c) Adjust Positions of Wafer Centers to Account for Winds During Cloud Rise

Figure 1. Operations of the Cloud Rise – Transport Interface Module

The Transport Module takes as input the coordinates of the center of each subdivision, at which position it assumes residence of a representative central particle of given mass and size. The time of input of the central particle to the Transport Module also is given. A diagrammatic representation of a cloud subdivision and its defining parameters as accepted by the Transport Module are shown in Figure 2. Within the Transport Module the trajectory of each cloud subdivision

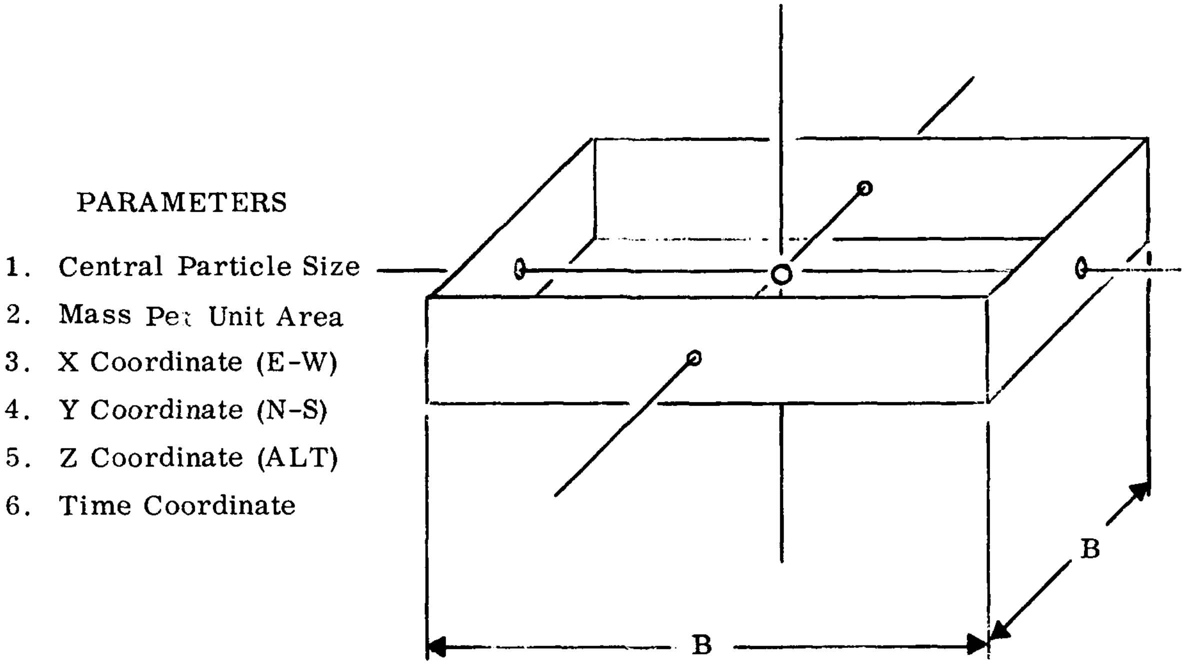


Figure 2. The Elementary Cloud Subdivision and Its Characterization (B is the dimension of all cloud subdivisions at the time of their definition.)

(represented by its central particle) is determined independently of all others and transport ceases when the central particle lands on the topography.

Within the Transport Module there are two systems for the description of atmospheric flow: the primary, or "macro," system; and the secondary, or "local," system. The use of these systems of description, however, is merely suggestive of but not restricted to the macrometeorological and local meteorological scales. In the macroscale description relatively large cells may be employed, and the totality of cells may include a vast volume of atmosphere perhaps on a macrometeorological scale. In the local atmospheric system cells more freedom is allowed in the mode of circulation description. Within each local circulation system unique particle transport procedures can apply. For practical reasons the DELFIC system restricts the researcher to use, at any one time, only a small number of local circulation systems that are defined within specified boundaries. Where "local" and "macro" description systems overlap, the former take precedence since they are capable of greater precision.

PHYSICAL AND MATHEMATICAL MODELS

Fallout Particle Kinematics

Relationship Between Wind Field and Particle Velocity

The fundamental equations that describe the motion of fallout particles (which are typically greater than 10μ in diameter) in the wind field are the momentum equation

$$\frac{d\underset{\sim}{V}_p}{dt} = -\left\{ \underset{\sim}{V}_p(t) - \underset{\sim}{V}_w[\underset{\sim}{r}(t), t]\right\} \phi\left(|\underset{\sim}{V}_p - \underset{\sim}{V}_w|\right) + \underset{\sim}{G} \tag{1}$$

and the displacement equation

$$\frac{d\underset{\sim}{r}}{dt} = \underset{\sim}{V}_p \quad , \tag{2}$$

where $\underset{\sim}{V}_p$ and $\underset{\sim}{V}_w$ are the particle and wind velocity respectively, $\underset{\sim}{G} = -G\underset{\sim}{k}$ where G is the gravitational constant and $\underset{\sim}{k}$ is a unit vector which points in the positive z direction, $\underset{\sim}{r}$ is the particle's position, and $\phi(|\underset{\sim}{V}_p - \underset{\sim}{V}_w|)$ is a friction function defined so that the frictional force per unit mass between the particle and the wind is given by*

$$F = -\left(\underset{\sim}{V}_p - \underset{\sim}{V}_w\right) \phi\left(|\underset{\sim}{V}_p - \underset{\sim}{V}_w|\right) \quad . \tag{3}$$

*A commonly used expression for ϕ in the pressure flow regime is

$$\phi = \frac{1}{2}\frac{C_D}{m}\rho A\,|\underset{\sim}{V}_p - \underset{\sim}{V}_w| = K|\underset{\sim}{V}_p - \underset{\sim}{V}_w| \quad ,$$

while in the Stokes law regime ϕ is a constant.

We have shown in Appendix A of Ref. 1 that for all but the most extreme conditions of airflow, for example, tornadoes, the components of particle velocity are given by

$$V_{px} = U \quad , \tag{4}$$

$$V_{py} = V \quad , \tag{5}$$

and

$$V_{pz} = -V_F + W \quad , \tag{6}$$

where U, V, and W are the x, y, and z components of the wind velocity, respectively, and V_F is the still-air particle settling rate. In effect we have been able to solve the momentum equation for the fallout particle, thus reducing the dynamics of the transport problem to the solution of the position equation.

Particle Settling Rates

We have performed a comprehensive survey of the methods used for computing particle settling rates as given both in the open literature and in the literature on fallout prediction methods.[1] On the basis of this survey, we have concluded that the equations of Davies[2] for spheres are most appropriate for use in the DOD Land Fallout Prediction System. The following procedure is used in computing particle settling rates:

1. The dimensionless quantity $C_D R^2$, where C_D is the drag coefficient and R is the Reynolds number, is evaluated by the equation

$$C_D R^2 = \frac{4G\rho\rho_p d^3}{3\eta^2} \quad , \tag{7}$$

where G is the acceleration of gravity, ρ and ρ_p are the densities of air and particle, d is the particle diameter, and η is the dynamic viscosity of the air.

2. The Reynolds number is evaluated from the Davies polynomials:

$$R = \frac{C_D R^2}{24} - 2.3363 \times 10^{-4}\left(C_D R^2\right)^2 + 2.0154 \times 10^{-6}\left(C_D R^2\right)^3$$
$$- 6.9105 \times 10^{-9}\left(C_D R^2\right)^4 , \quad C_D R^2 < 140 \tag{8}$$

or

$$\log_{10} R = -1.29536 + 0.986\left(\log_{10} C_D R^2\right) - 0.046677\left(\log_{10} C_D R^2\right)^2$$
$$+ 0.0011235\left(\log_{10} C_D R^2\right)^3 , \quad 100 < C_D R^2 < 4.5 \times 10^7 . \tag{9}$$

3. The settling velocity V_F is computed from

$$V_F = \frac{R\eta}{\rho d} , \tag{10}$$

4. For small particles at high altitudes, the settling velocity must be multiplied by a drag slip correction, f, where

$$f = 1 + \frac{2.33 \times 10^{-4}}{d\rho} , \tag{11}$$

and d and ρ are in microns and grams per cubic centimeter, respectively.

We have concluded[1] that methods commonly used in the past to correct particle fall rates for shape effects in fallout prediction calculations are incorrect. Apparently it is true that irregularity of shape can have a significant influence on settling rate; however, the only precise information of a general nature that seems to be available is that a particle of spherical shape falls at a rate that is a maximum for particles of equivalent volume of all shapes. In addition, irregularity of shape can cause deviation of particle trajectories from the vertical in still air. It is known that both of these effects become more pronounced with increase in Reynolds number. Unfortunately, so little experimental work has been done for particles in the pressure flow range (i.e., for large Reynolds numbers) that the importance of these effects to fallout prediction calculations cannot be precisely determined. Additional studies of these effects should be performed to resolve the issue.

Appendix B of Ref. 1 presents the details of our study and a comparison of particle settling rate computation methods.

Effect of Atmospheric Diffusion on Particle Transport

In our model of cloud subdivision transport a segment of cloud volume of height ΔZ and lateral dimensions $2X_o$, $2Y_o$ (see Figure 3) is assumed to move through the atmosphere as a rigid body if turbulent diffusion is absent. To be sure, it is assumed (still neglecting diffusion) that the initial extent of the cloud subdivision is small enough so that the equation of motion of a hypothetical particle located at the periphery will not differ from that at the center. The motion of the center is determined from the conventional transport equations as previously developed (i.e., Eqs. (4)-(6)).

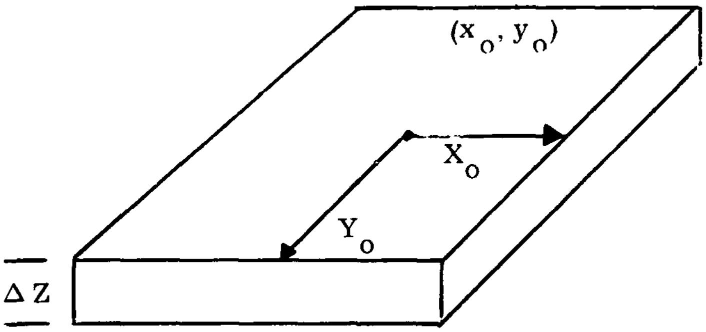


Figure 3. Segment of Cloud Volume

In reality, the cloud subdivision represents a group of particles (of a particular size range) whose total number is N and whose initial uniform lateral density[*] is

$$\sigma_o = \frac{N}{4Y_oX_o} \left(\text{particles - m}^{-2}\right) \; . \tag{12}$$

During transport, turbulent diffusion tends to disperse the particles of the cloud subdivision so that by the time the subdivision reaches the ground, its shape will have changed and its particle density, σ, will have decreased and become nonuniform.

The increase in lateral area is due to the cumulative effect of diffusion of all the particles contained in the slice. If the origin is established at the center of the slice, the lateral density of particles, $P(x, y, t)$, at a time t is given by

$$P(x, y, t) = \sigma_o \int_{-X_o}^{+X_o} \int_{-Y_o}^{+Y_o} G(x - x', y - y', t) \, dx' \, dy' \quad , \tag{13}$$

where the diffusion kernel $G(x - x', y - y', t)$ is given by

$$G = (2\pi Dt)^{-1} \exp \left\{ - \left[(x - x')^2 + (y - y')^2 \right] / 2Dt \right\} \quad , \tag{14}$$

with D being the diffusion constant. Consideration of Eqs. (13) and (14) show that $P(x, y, t)$ is defined over the entire x, y plane, but as an approximation to the theoretical result for computational purposes we have chosen to construct an equivalent rectangular segment of uniform surface density σ with dimensions defined as X, Y. These equivalent dimensions are determined by requiring that the mean-square

[*] The term lateral density is used to refer to the surface density (particle/unit area) that would result if the particles represented by a cloud subdivision were deposited vertically onto a horizontal plane.

displacements $\overline{x^2}$, $\overline{y^2}$ of the rectangular segment be the same as those computed from the exact probability distribution P(x, y, t).

It is easy to show that for a uniform distribution, $\overline{x^2}$ and $\overline{y^2}$ are related to the limiting dimensions via the formulas:

$$\overline{x^2} = 1/3\,X^2 ; \; \overline{y^2} = 1/3\,Y^2 \quad . \tag{15}$$

On the other hand, we have

$$\overline{x^2} = \frac{\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} x^2 P(x,y,t)\,dx\,dy}{4\sigma_o X_o Y_o} = Dt + 1/3\,X_o^2 \ ,$$

and (16)

$$\overline{y^2} = \frac{\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} y^2 P(x,y,t)\,dx\,dy}{4\sigma_o X_o Y_o} = Dt + 1/3\,Y_o^2 \ .$$

The equivalent dimensions of the slice at time t are thus given by

$$X^2 = X_o^2 + 3Dt \ ,$$

and (17)

$$Y^2 = Y_o^2 + 3Dt \ ,$$

with corresponding lateral density

$$\sigma = \frac{N}{4XY} \quad . \tag{18}$$

The user is referred to Pasquill's "Atmospheric Diffusion"[3] for a discussion on reasonable estimates of D.

Wind-Field Description

As previously mentioned, there are two complementary and simultaneously compatible modes for describing the wind field: (1) the macrowind description system which makes use of a numerical approximation to a complete three dimensional wind field derived from observed data and is of greatest general utility; and (2) the local circulation description system which makes use of analytical representations of special atmospheric situations (e.g., sea breezes or mountain winds). These local systems also are three dimensional and can coexist with a macrowind field, in which case they override the macrowind field within the volume of space common to both. These modes of wind-field description are described in detail in the subsequent sections.

Macrowind Fields

The macrowind-field descriptions are accomplished as follows. A Cartesian coordinate system that encompasses the region of close-in fallout is established with arbitrary origin. With reference to this coordinate system, grid square arrays are specified on horizontal planes at arbitrarily spaced intervals in the vertical direction. Figure 4 illustrates how such a set of strata is used to fill the volume of atmosphere of interest. Each stratum is further subdivided into a number of wind cells in a regular manner as is shown in Figure 5.

To assign vectors to wind cells, the user must first specify as input a data set of wind vectors and vector positions. This data set can be arbitrary in number and distributed in an arbitrary manner throughout the atmospheric volume of interest. The program then determines and associates a wind vector with each wind cell in the volume of interest. These wind cell vectors are based on the input data, and there are three interpolation-extrapolation computational methods available for use in determining them.

In the first option the program assigns to each wind cell the data vector nearest the cell's center. The second option uses a weighted average of nearest data vectors, where the user is free to specify both the number and the distances of the vectors to be considered. The third option uses a statistically derived three dimensional linear model of the atmosphere based on the N nearest data vectors to perform the required interpolation or extrapolation for each cell. The method to be used in any particular

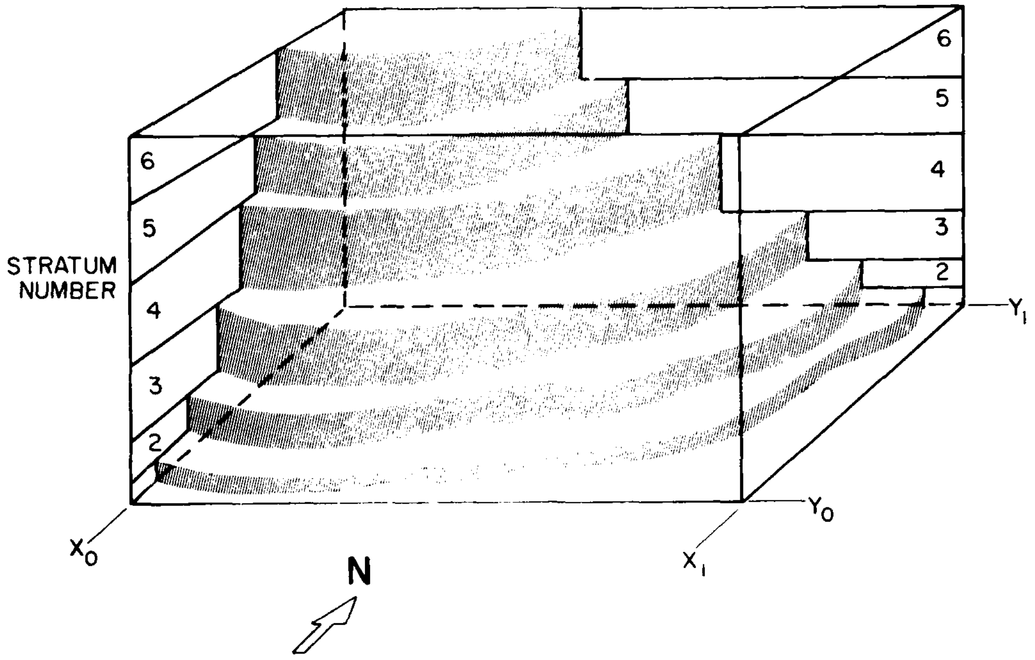


Figure 4. Strata within the Specified Wind Field Volume (illustrated for six strata)

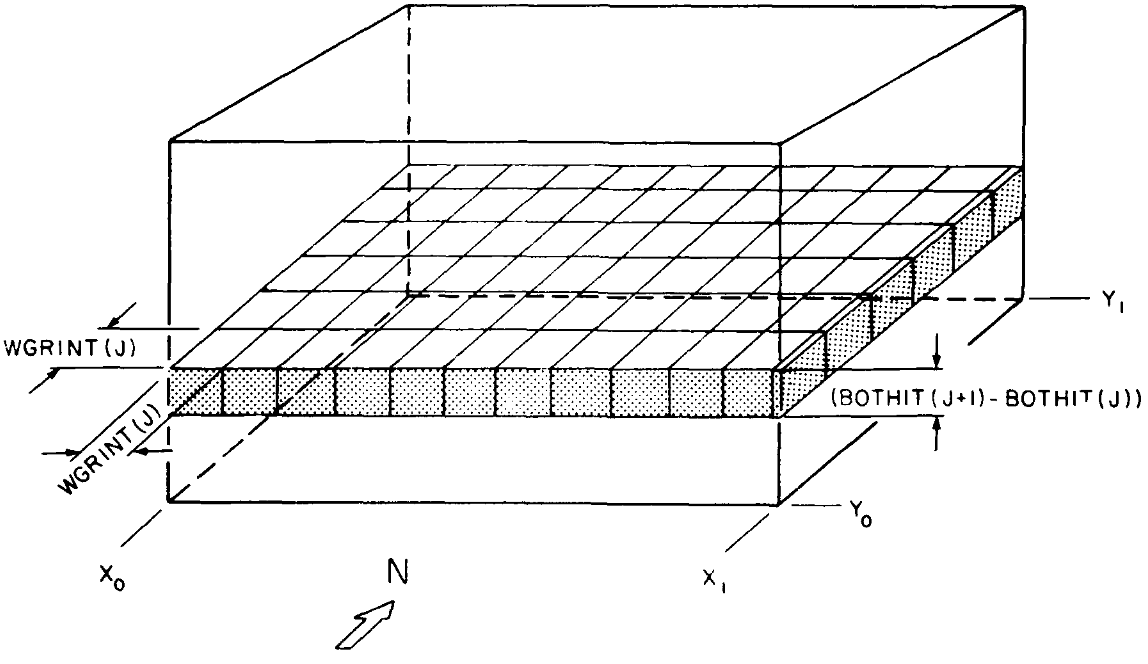


Figure 5. Wind Cells — Subdivisions of a Stratum (illustrated for the Jth stratum from the bottom)

case must be determined on the basis of the quantity and quality of the data available. The notation used in the explanation of the three methods is as follows:

$\underset{\sim}{R}_i$ = position of ith observed wind velocity vector relative to the wind-field-array grid point $\underset{\sim}{R}_o$

$\underset{\sim}{V}_i$ = measured wind velocity at position $\underset{\sim}{R}_i$

$\underset{\sim}{V}_o$ = wind velocity at a wind-field-array grid point $\underset{\sim}{R}_o$. $\underset{\sim}{V}_o$ is to be determined from $\underset{\sim}{R}_i$ and $\underset{\sim}{V}_i$.

The Closest Datum Method. In this method the velocity at the grid point is assumed to be the same as that of the closest datum point. This will probably be a good approximation if the location of a measurement is sufficiently close to the arbitrary point.

The Preferential-Weighting Method. In the preferential weighting method $\underset{\sim}{V}_o$ is computed as a weighted average of the velocities from observations that lie within distance β from the grid point in the horizontal plane and distance α from the grid point in the vertical direction. Specifically, the relationship between $\underset{\sim}{V}_o$ and $\underset{\sim}{V}_i$ is given by

$$\underset{\sim}{V}_o = \sum_{i=1}^{N} f_i \underset{\sim}{V}_i \quad ; \tag{19}$$

where

$$\sum_{i=1}^{N} f_i = 1 \quad . \tag{20}$$

A weighting method described by Cressman[4] has been used in deriving an expression for f_i in the form

$$f_i = \frac{\left(\dfrac{\alpha^2 \quad z_i^2}{\alpha^2 + z_i^2}\right)\left(\dfrac{\beta^2 - x_i^2 - y_i^2}{\beta^2 + x_i^2 + y_i^2}\right)}{\left(\displaystyle\sum_{k=1}^{N} \dfrac{\alpha^2 - z_k^2}{\alpha^2 + z_k^2}\right)\left(\dfrac{\beta^2 - x_k^2 - y_k^2}{\beta^2 + z_k^2 + y_k^2}\right)} \quad . \tag{21}$$

The parameters α, β, and N are specified by the user, α and β have the physical significances described previously. The calculations of the f_i are performed so that whenever a factor in Eq. (21) is found to be negative, its value is replaced with zero. If N is specified to be less than the total number of observations, only the N observations closest to the grid point are considered in the calculations.

The Least-Squares Method. Here, we assume that each velocity component is an analytic function of position. Since the wind velocity in the macrowind field will not undergo very great spatial variations in a short distance, it becomes possible to approximate each component of the wind velocity by the first few terms of the Taylor expansion taken about the grid point as origin. We can then write

$$u = u_o + (\nabla u)_o \cdot \underset{\sim}{R} \ ,$$

$$v = v_o + (\nabla v)_o \cdot \underset{\sim}{R} \ , \tag{22}$$

and

$$w = w_o + (\nabla w)_o \cdot \underset{\sim}{R} \ ,$$

where u_o, v_o, and w_o are the x, y, and z components of the wind velocity at the origin. By least-squares fitting of Eq. (22) to the data points, we can determine the twelve unknown constants u_o, v_o, w_o, $(\nabla u)_o \equiv \underset{\sim}{A}$, $(\nabla v)_o \equiv \underset{\sim}{B}$, and $(\nabla w)_o \equiv \underset{\sim}{C}$. Actually, the computation breaks down into three separate parts involving $(u_o, \underset{\sim}{A})$, $(v_o, \underset{\sim}{B})$, and $(w_o, \underset{\sim}{C})$. To illustrate the procedure, we shall outline the method for computing u_o. If U_i denotes the x component of wind velocity at the ith sounding station, the ith residual is given by

$$\xi_i = U_i - u_i = U_i - \left(u_o + A_x x_i + A_y y_i + A_z z_i\right) \quad . \tag{23}$$

The constants u_o, A_x, A_y, and A_z are determine^d by the least-squares method by minimizing the functional

$$F\left(u_o, \underset{\sim}{A}\right) = \sum_{i=1}^{N} \xi_i^2 \tag{24}$$

with respect to these four parameters. The four linear equations so deduced are

$$\frac{\partial F}{\partial u_o} = 0 = -\sum U_i + \sum \left(u_o + \underset{\sim}{A} \cdot \underset{\sim}{R}_i\right) , \tag{25}$$

$$\frac{\partial F}{\partial A_x} = 0 = -\sum U_i x_i + \sum \left(u_o + \underset{\sim}{A} \cdot \underset{\sim}{R}_i\right) x_i , \tag{26}$$

$$\frac{\partial F}{\partial A_y} = 0 = -\sum U_i y_i + \sum \left(u_o + \underset{\sim}{A} \cdot \underset{\sim}{R}_i\right) y_i , \tag{27}$$

and

$$\frac{\partial F}{\partial A_z} = 0 = -\sum U_i z_i + \sum \left(u_o + \underset{\sim}{A} \cdot \underset{\sim}{R}_i\right) z_i . \tag{28}$$

Introducing the averaged quantities,

$$\begin{gathered}
\bar{u} = \left(\frac{1}{N}\right) \sum U_i ,\ \bar{x} = \left(\frac{1}{N}\right) \sum x_i ,\ \bar{y} = \left(\frac{1}{N}\right) \sum y_i , \\
\bar{z} = \left(\frac{1}{N}\right) \sum z_i ,\ \overline{ux} = \left(\frac{1}{N}\right) \sum U_i x_i ,\ \overline{uy} = \left(\frac{1}{N}\right) \sum U_i y_i , \\
\overline{uz} = \left(\frac{1}{N}\right) \sum U_i z_i ,\ \overline{x^2} = \left(\frac{1}{N}\right) \sum x_i x_i ,\ \overline{xy} = \left(\frac{1}{N}\right) \sum x_i y_i , \\
\overline{xz} = \left(\frac{1}{N}\right) \sum x_i z_i ,\ \overline{yz} = \left(\frac{1}{N}\right) \sum y_i z_i ,\ \overline{y^2} = \left(\frac{1}{N}\right) \sum y_i y_i ,
\end{gathered} \tag{29}$$

and

$$\overline{z^2} = \left(\frac{1}{N}\right) \sum z_i z_i ,$$

gives the following matrix equation for u_o and $\underset{\sim}{A}$:

$$\begin{pmatrix} 1 & \bar{x} & \bar{y} & \bar{z} \\ \bar{x} & \overline{x^2} & \overline{xy} & \overline{xz} \\ \bar{y} & \overline{xy} & \overline{y^2} & \overline{yz} \\ \bar{z} & \overline{xz} & \overline{yz} & \overline{z^2} \end{pmatrix} \begin{pmatrix} u_o \\ A_x \\ A_y \\ A_z \end{pmatrix} = \begin{pmatrix} \bar{u} \\ \overline{ux} \\ \overline{uy} \\ \overline{uz} \end{pmatrix} \quad . \tag{30}$$

By use of conventional matrix inversion techniques, Eq. (30) can be solved for u_o. We have

$$u_o = \gamma_i \bar{u} + \gamma_2 \overline{ux} + \gamma_3 \overline{uy} + \gamma_4 \overline{uz} \quad , \tag{31}$$

where

$$\begin{aligned} \gamma_1 &= \frac{B^{11}}{|B|} \quad , \\ \gamma_2 &= \frac{B^{21}}{|B|} \quad , \\ \gamma_3 &= \frac{B^{31}}{|B|} \quad , \end{aligned} \tag{32}$$

and

$$\gamma_4 = \frac{B^{41}}{|B|} \quad ,$$

in which $|B|$ denotes the determinant of the matrix Eq. (30). The quantities B^{ki} are the cofactors which equal $(-1)^{i+k}$ times the complementary minor of the matrix element B_{ki}. It is easy to show that the y and z components of velocity are given by

$$v_o = \gamma_1\bar{v} + \gamma_2\overline{vx} + \gamma_3\overline{vy} + \gamma_4\overline{vz} \ , \tag{33}$$

and

$$w_o = \gamma_1\bar{w} + \gamma_2\overline{wx} + \gamma_3\overline{wy} + \gamma_4\overline{wz} \ , \tag{34}$$

where the averaged quantities in Eqs. (33) and (34) are of the same nature as those shown in Eq. (29) with the replacement of U_i with V_i and W_i.

Some reflection shows that the determinant of the matrix can equal zero when the measured points lie on the same plane or on a line. (For example: if $z = z^*$ is the same for all stations, then the fourth column of B is z^* times the first and $|B|$ vanishes.) This is a manifestation of the impossibility of passing a different plane through the N points. We have provided for these degenerate cases in the computer program. When the determinant of B is very small, we revert back to the preferential-weighting method.

Local Circulation Systems

Provision has been made to incorporate local circulation systems in the computer program to afford prediction of the wind velocity in regions where (1) direct measurements of the wind velocity are not readily available and (2) the density of measuring stations is not adequate to account for rapid spatial changes in the wind field. At present, two such local circulation systems are available: the orographic and sea-breeze systems.

The regions controlled by these models are bounded by planes perpendicular to the coordinate axes. Inside these regions, wind vectors are computed for specific circulation model parameters. Figure 6 represents three of these local circulation cells as they may be superimposed upon the macrostratum and wind cell structure. The important physical features of these local circulation systems, as they pertain to user application, are now discussed, although the details of the theory in each case are presented in Appendixes A and B, respectively.

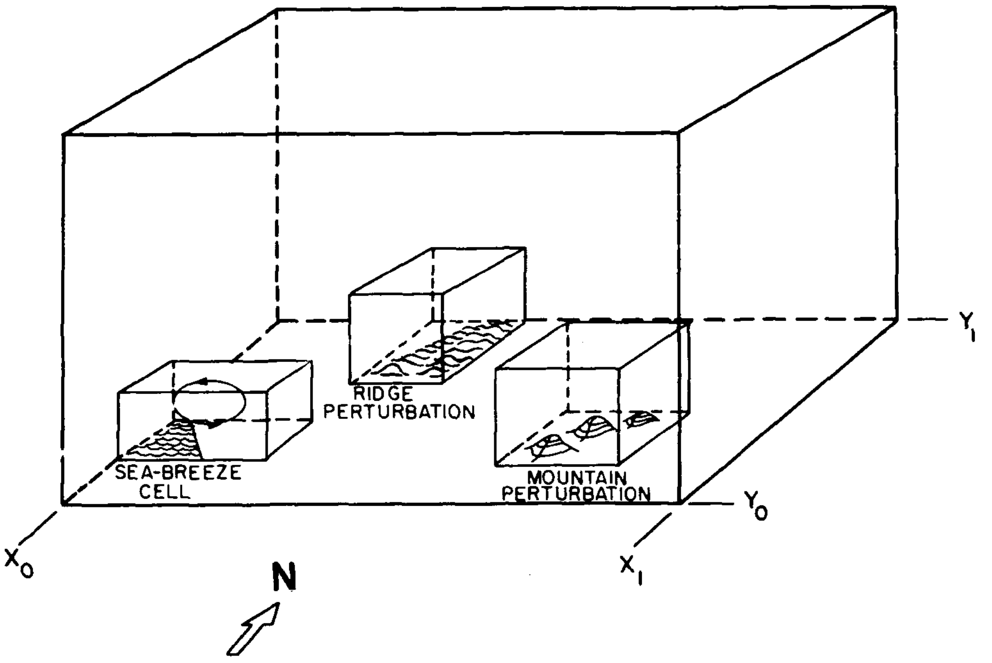


Figure 6. Wind-Field Volume with Superimposed Local Circulation System Cells

Orographic Effects. The theoretical model of orographic flow is intended for use in regions where suitable meteorological data are not readily available. Specifically, the model assumes that in the absence of the variable terrain region under consideration, a certain uniform steady velocity field would exist. The mountains and valleys then cause the assumed flow to change, and it is the resulting wind field which is computed by the model. It is possible to compute the wind field in a region which contains several orographic features by first computing the wind field due to a single one and then summing up the effects. This procedure works as follows:

Let u_o be the velocity of the unperturbed flow (i.e. the flow that would exist in the absence of the mountains and valleys). Now orient the coordinate system so that the x direction points along u_o, and let the y axis be perpendicular to u_o and the z axis point in the direction of the zenith. The functions u(x, y, z), v(x, y, z), and w(x, y, z) denote the x, y, and z components of the wind velocity respectively.

We have found that a suitable mathematical representation for a single mountain is

$$z = f(x, y) = \frac{h a^3}{\left(a^2 + r^2\right)^{3/2}} , \tag{35}$$

where z is the elevation of the mountain, expressed as a function of

$$r = \left(x^2 + y^2\right)^{1/2} , \tag{36}$$

the horizontal distance from the center of the mountain; h is the maximum elevation of the mountain as can be seen by setting r = 0 in Eq. (35); and a is a characteristic width of the mountain (when r = a the elevation z = 0.35h). The components of wind velocity resulting from the mountain whose vertical position with distance is given by Eq. (35) is given by:

$$u(x, y, z) = u_o \left[1 + \left(a^2 h\right) \frac{\left(y^2 + \lambda^2 - 2x^2\right)}{\left(r^2 + \lambda^2\right)^{5/2}} \right] , \tag{37}$$

$$v(x, y, z) = -3u_o\left(a^2 h\right) \frac{xy}{\left(r^2 + \lambda^2\right)^{5/2}} , \tag{38}$$

and

$$w(x, y, z) = -3u_o\left(a^2 h\right) \frac{\lambda x}{\left(r^2 + \lambda^2\right)^{5/2}} , \tag{39}$$

where

$$\lambda = (z + a) . \tag{40}$$

Obviously, the foregoing expressions for the components of wind velocity are applicable for

$$z \geq f(x, y) \tag{41}$$

(i.e. for those points which lie above the ground). Equations (37)-(39)can be used to describe the flow of wind over a valley whose mathematical description is like that of an inverted mountain. For this situation we merely replace h by -h, the maximum depression of the mountain.

Another important obstacle to be considered is a mountain ridge whose crestline makes an arbitrary angle γ with respect to the direction of the unperturbed flow u_o. The pertinent geometric details are shown in Figure 7.

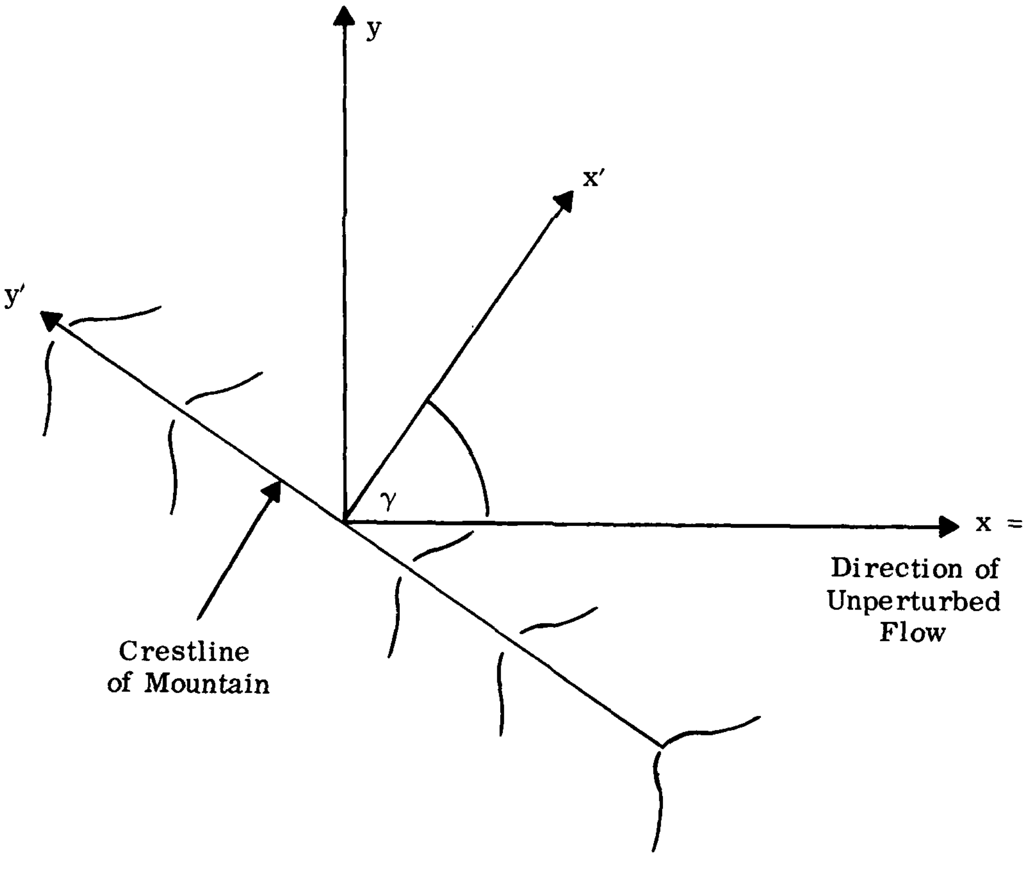


Figure 7. Mountain Ridge Not Perpendicular to Flow

The mathematical description of the elevation of the mountain ridge when viewed along the y′ axis is given by the expression

$$z^* = \frac{h}{1 + (x'/a)^2} \quad , \tag{42}$$

where h is the maximum elevation of the ridge; a, in this case, is the half width (z = 0.5h when x′ = a); and the x and y coordinates are related to x′ and y′ by the equations

$$\begin{aligned} x &= x' \cos\gamma - y' \sin\gamma \ , & x' &= x \cos\gamma + y \sin\gamma \ ; \\ y &= x' \sin\gamma + y' \cos\gamma \ , & y' &= -x \sin\gamma + y \cos\gamma \ . \end{aligned} \tag{43}$$

The wind velocity components referred to the x, y, z coordinates are given by

$$u = u_o - u_o(ah) \cos^2\gamma \frac{(x \cos\gamma + y \sin\gamma)^2 - \lambda^2}{\left[(x \cos\gamma + y \sin\gamma)^2 + \lambda^2\right]^2} \quad , \tag{44}$$

$$v = -u_o(ah) \cos\gamma \sin\gamma \frac{(x \cos\gamma + y \sin\gamma)^2 - \lambda^2}{\left[(x \cos\gamma + y \sin\gamma)^2 + \lambda^2\right]^2} \quad , \tag{45}$$

and

$$w = -2u_o(ah) \lambda \cos\gamma \frac{(x \cos\gamma + y \sin\gamma)}{\left[(x \cos\gamma + y \sin\gamma)^2 + \lambda^2\right]^2} \quad , \tag{46}$$

where

$$\lambda = z + a \quad .$$

It should be carefully noted that u, v, and w do not depend on y', as can be seen from the substitution $x' = x \cos\gamma + y \sin\gamma$ in Eqs. (44)-(46), so that the origin of the mountain ridge can be located anywhere along the crestline. Equations (44)-(46) can also be applied to a valley ridge whose shape is that of an inverted mountain ridge, with the replacement of h by -h.

In summary then, we can compute the wind field due a mountain, inverted mountain (valley), mountain ridge, and inverted mountain ridge (valley ridge). For the single mountain (valley) the expressions for the velocity are referred to the center of the mountain whose coordinates can be denoted by

$$\left(x_i, y_i\right) .$$

That is, if x, y and z denote the point in question, then the components of the wind field due to the mountain in question that are computed at this point are given by

$$u_i(x, y, z) = u\left(x - x_i, y - y_i, z\right) ,$$

$$v_i(x, y, z) = v\left(x - x_i, y - y_i, z\right) , \qquad (47)$$

and

$$w_i(x, y, z) = w\left(x - x_i, y - y_i, z\right) ,$$

where $u(x - x_i, y - y_i, z)$, $v(x - x_i, y - y_i, z)$, and $w(x - x_i, y - y_i, z)$ are obtained from Eqs. (37)-(39) with the replacement of x by $x - x_i$, and y by $y - y_i$. As in Eq. (41), the inequality

$$z \geq z_i^* = f_i\left(x - x_i, y - y_i\right) \qquad (48)$$

must also be satisfied.

Precisely the same considerations concerning the calculation of the wind field apply for the mountain (valley) ridge. That is, Eqs. (44)-(46) give the velocity of the wind field when x and y are replaced by $x - x_i$ and $y - y_i$, where x_i and y_i are the coordinates of the center of the ridge and z lies above the ground.

As demonstrated in Appendix A, the theory shows that the principle of superposition of ground disturbances is applicable under most conditions, the exceptions to which are subsequently discussed. What this means is that in a region where the topography can be described by the equation

$$z_T^* = \sum_i f_i\left(x - x_i, y - y_i\right) \quad , \tag{49}$$

where $f_i(x - x_i, y - y_i)$ is the mathematical description of a particular orographic feature (referred to a suitable origin whose coordinates are x_i, y_i), the resulting velocity field can be written as

$$u(x,y,z) = \sum_i u_i\left(x - x_i, y - y_i, z\right) \quad ,$$

$$v(x,y,z) = \sum_i v_i\left(x - x_i, y - y_i, z\right) \quad , \tag{50}$$

and

$$w(x,y,z) = \sum_i w_i\left(x - x_i, y - y_i, z\right) \quad ,$$

where $u_i(x - x_i, y - y_i, z)$, $v_i(x - x_i, y - y_i, z)$, and $w_i(x - x_i, y - y_i, z)$ are the contributions to the velocity field resulting from the orographic feature whose mathematical description is given by $f_i(x - x_i, y - y_i)$. To be sure, we have assumed in this model that the topographical description can be resolved into combinations of mountains, valleys, and mountain and valley ridges whose individual mathematical description is given by Eqs. (35) or (42) with h either positive or negative. In the event that this is not feasible, or satisfactory, the user can use the general technique as outlined in Appendix A to compute the wind field for an arbitrary topographical description.

Thus at this time the user is obliged to represent the topography through combinations of the four features just discussed. The point to be carefully noted is that the resulting analytical expression for the topography, which will be of form given by Eq. (49), should as closely as possible resemble the terrain. Suppose there are two mountain ridges each of half width a separated by a distance ℓ_1, as shown in Figure 8(a).

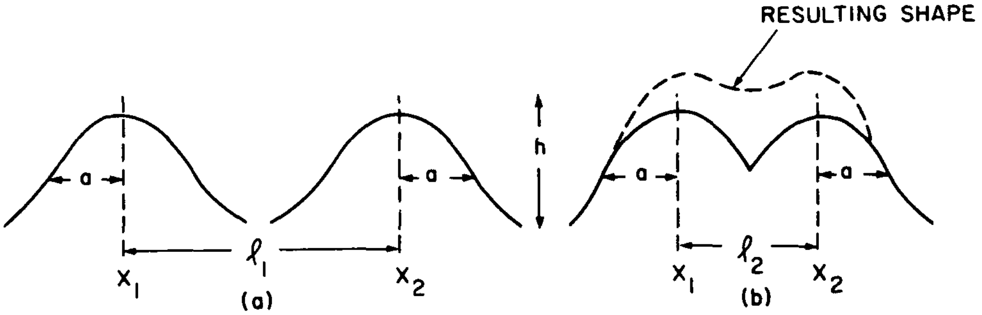


Figure 8. Mountain Ridge Separations

If ℓ_1 is large compared to a, then with good approximation the topography can be represented by the equation

$$z_T^* = \frac{h}{1 + \left(x - x_1\right)^2 / a^2} + \frac{h}{1 + \left(x - x_2\right)^2 / a^2}\ , \tag{51}$$

because when z_T^* is evaluated in the vicinity of the second mountain ridge (i.e., $x \approx x_2$) the contribution from the first term is negligible. Evaluating z_T^* at $x = x_2$ gives

$$z_T^*\left(x = x_2\right) = \frac{h}{1 + \left(\ell_1^2 / a^2\right)} + h\ ,$$

which if $\ell_1 >> a$ approximately equals h, the contribution from the second ridge only. Now consider the same ridges, but this time separated by a smaller distance ℓ_2 (Figure 8(b)). Equation (51) will no longer be adequate because $z_T^*(x = x_2)$ becomes

$$z_T^*\left(x = x_2\right) = \frac{h}{1 + \left(\ell_2^2 / a^2\right)} + h \ ,$$

which can be significantly greater than h if ℓ_2 is not very much larger than a. Thus the dashed line shown in Figure 8(b) might be the resulting topographical shape if Eq. (51) were used. A possible method for circumventing problems of this type is to use an expression of the form

$$z_T^* = \frac{h'}{1 + \left(x - x_1\right)^2 / a'^2} + \frac{h'}{1 + \left(x - x_2\right)^2 / a'^2} \ ,$$

where h' and a' are "adjusted" parameters, deduced by developing a best fit approximation to the actual terrain.

In brief, the resulting analytic expression for the topography should be deduced by a "best fit" procedure.

As mentioned earlier, there are certain limitations of the model which the user should be aware of. These restrictions are basically of two types and are concerned with the extent or actual size of the orographic flow of the local circulation system, and the shape of the terrain. These aspects of the problem are discussed in detail in Appendix A; however, a summary of the major conclusions is as follows:

1. Size Limitations

The theoretical model is based upon a perturbation treatment of the usual hydrodynamic-thermodynamic equations under the assumption that an adiabatic atmosphere prevails. The relationship between the change in the wind field $\Delta \underset{\sim}{v}(x, y, z)$ and the curvature of the terrain is deduced by first expressing the three components of $\Delta \underset{\sim}{v}$ (namely $\Delta v_i(x, y, z)$) in a spatial Fourier transform representation,

$$\Delta v_i(x, y, z) = \int A_i(\underset{\sim}{k})\, e^{i\underset{\sim}{k} \cdot \underset{\sim}{r}}\, d^3k \quad ,$$

and then solving for the $A_i(\underset{\sim}{k})$. The solution for the $A_i(\underset{\sim}{k})$ involves the derivation of the dispersion relationship for the system, which basically connects the vertical attenuation constant of the velocity field to the periodicity of the terrain. This relationship is of the form

$$k_z = k_z\left(k_x, k_y\right) \quad ,$$

and becomes greatly simplified for (1) short wavelengths and (2) when the Coriolis effect is neglected. It is in fact these simplifications of the dispersion relationship which yield the relatively simple forms of the wind fields. The short wavelength restriction requires that the area designated as a local circulation region be no greater than 50 mi in one direction. On the other hand, the neglect of the Coriolis effect requires that the extent of the local circulation system, L, be no greater than

$$d = 24 u_{om} \quad , \tag{52}$$

where u_{om} is the unperturbed wind velocity expressed in miles per hour. The condition for which

$$L < d = 24 u_{om}$$

is not really a limitation on the applicability of the theory for fallout prediction. If u_{om} is small, the perturbed wind velocity will also be small (as shown in the analysis) and terrain effects will not be important since the motion of the fallout particle will be essentially vertical. Thus, the expressions derived for the wind field by applying the calculation for short horizontal wavelengths and neglecting the Coriolis effect are entirely justified from the local circulation viewpoint. For all practical purposes the requirement

$$L \leq 50 \text{ mi}$$

is sufficient.

2. Shape Limitations

The first-order perturbation theory solution is only approximate and gives increasingly better results as the change in velocity, $\Delta \underset{\sim}{v}$, as compared to u_o diminishes. As shown in the analysis, $\Delta \underset{\sim}{v}$ increases with a corresponding increase of curvature or slope of the terrain; consequently, we can expect uncertainties between the unknown exact solution and the results computed from the first-order perturbation theory to also increase with an increase in slope. Roughly speaking, these uncertainties are of the order $|S|^2$, where S is the slope of the terrain. Clearly then, the model should not be used when S is very large, although the question of "how large" is not yet resolved. We have been able to partly compensate for the inadequacies of the calculation for the case of a mountain ridge whose crestline is perpendicular to the airflow, and we suggest that the conclusions drawn from this investigation be extended to all cases.

Fundamentally, we have found that the first-order perturbation theory underestimates the vertical lift in the case of the aforementioned mountain ridge (see Appendix A). This was demonstrated by showing that the calculated surface wind trajectory (which for the exact solution should be identical with the contour of the mountain ridge) actually intersected the ridge. The discrepancies between the exact and calculated surface trajectories increase with a corresponding increase in ridge slope, as given by the ratio of the maximum elevation, h, to the half width, a.

$$S = (h/a) \; .$$

However, by performing the calculations with a larger slope,

$$S' = h'/a \ ,$$

where h′ is larger than h, it becomes possible to make the calculated surface trajectory follow the mountain ridge contour. Figure 9 shows the relationship between the actual slope S and the required slope S′ whose use will partially compensate for the limitations of the first-order perturbation theory. Thus, if $|h|$ is the actual height of the mountain (valley) ridge, the calculations should be performed with an h′ given by

$$|h'| = |h|(S'/S) \ , \tag{53}$$

where the ratio S′/S is evaluated by first determining S (e.g. point A) and then finding the corresponding value of S′ (point B). We suggest that the modification in mountain ridge height, as given by Eq. (53), be extended to single mountains (valleys), although calculations supporting this

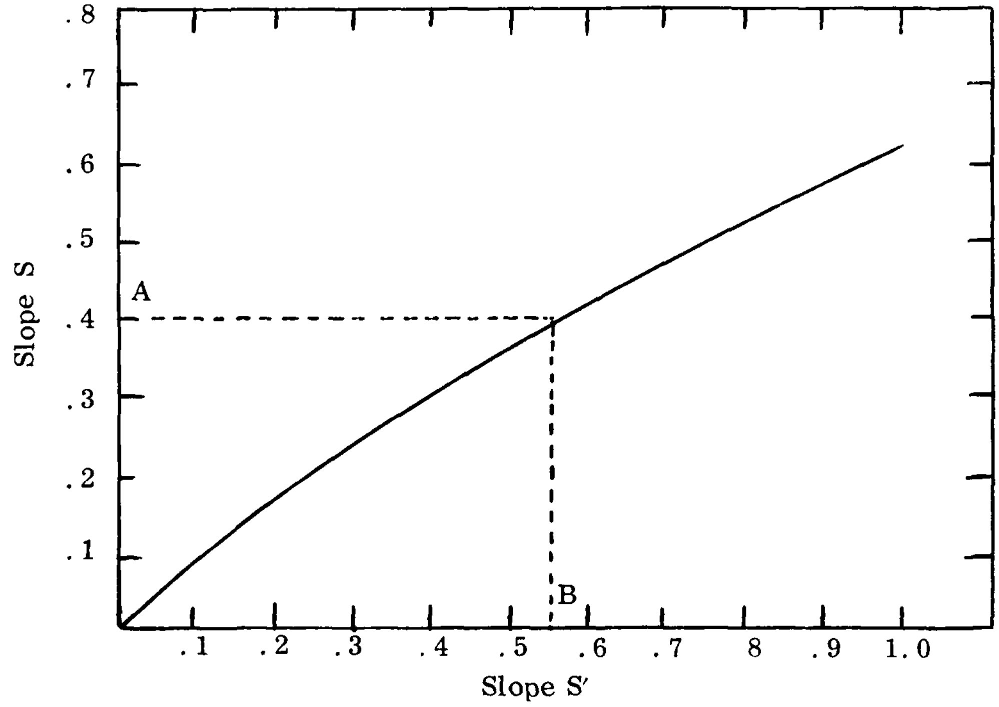


Figure 9. Slope Compensation

conjecture have not been rendered. The modification of elevation does not alleviate the shortcomings of first-order perturbation theory; consequently, we further suggest and, moreover, stipulate in the program itself that $S' \leq 0.6$.

It should also be noted in passing that the orographic effects extend indefinitely in altitude as can be seen by examining the mathematical expressions for the components of wind velocity. However, we have decided (based on a few sample calculations) to limit vertical consideration of an orographic region to three times the height of the highest obstacle in the region.

The Sea Breeze. The linearized model of the sea breeze as developed by Defant has been selected as the most suitable model for the sea breeze for two reasons: (1) it gives good agreement with experimental observation, and (2) the resulting analytical expressions for the components of the sea breeze are relatively simple from a computational standpoint. Defant[5] approaches the sea-breeze circulation problem in the sense of Lord Rayleigh's convection theory, the dynamics of which are governed by the continuity equation, the three momentum equations, the equation of state, and the heat-diffusion equation. By neglecting density variations in the continuity equation, and including them in the momentum equations since they modify the action of gravity, it becomes possible to construct a vorticity function from which the components of velocity in a plane perpendicular to the coast can be determined. Included in Defant's model is the assumption of an infinitely long coastline which points in the y direction; variations of the meteorological variables in this direction are neglected. The x axis is perpendicular to the coast and positive inland, while the z axis denotes the vertical.

Figure 10 shows the typical circulation pattern after sunrise when viewed along the direction of the coastline (positive y axis). In addition to the x-z circulation there is an accompanying y component of velocity which is related to the other components in a determined way, but is not shown in the figure. The driving force is

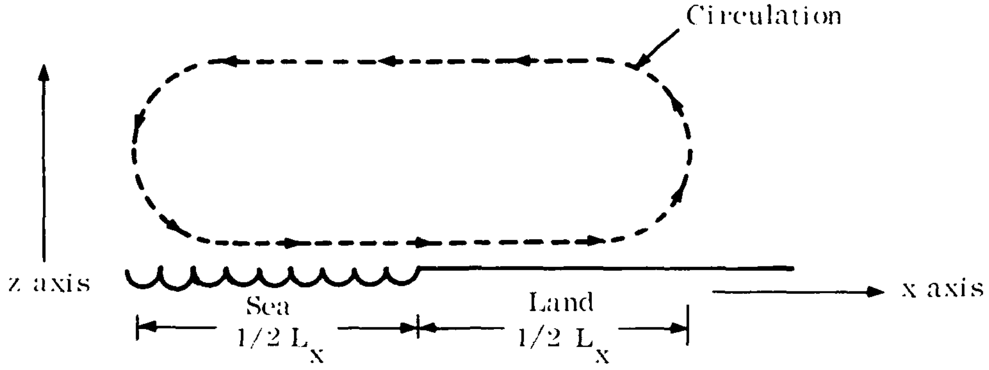


Figure 10. Sea-Breeze Circulation

of course the potential temperature differential at the surface, whose behavior with x and t is assumed to be given by

$$\theta(x, z = 0, t) = \sin \lambda x T(t) \quad , \tag{54}$$

where $\lambda = (\pi/2L_x)$ and T(t) is a function of time alone. The circulation pattern shown in Figure 10 occurs when the land temperature is higher than the water temperature (discounting the 1 hr or so lag time due to the inertia of the system). A positive value of T(t) corresponds to the surface temperature differential profile shown in Figure 11.

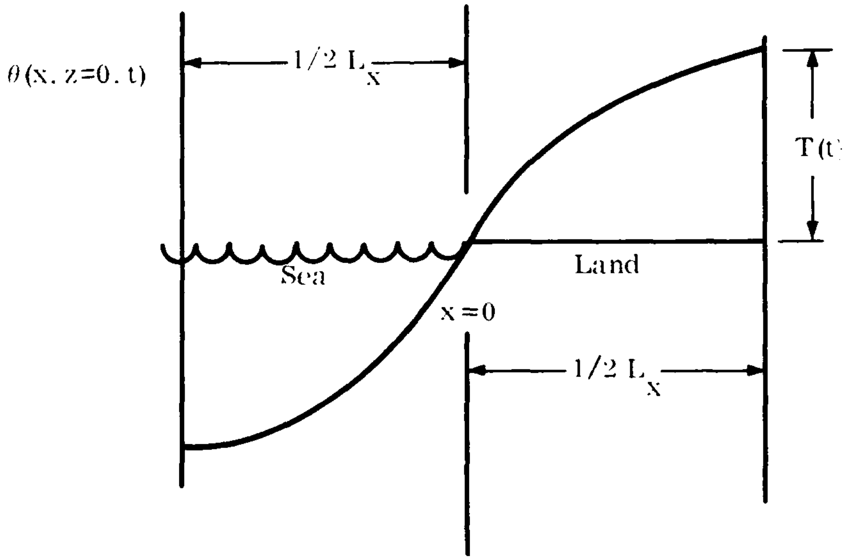


Figure 11. Temperature Differential Profile

According to the theory T(t) is expressible as a Fourier series in multiples of the sidereal day frequency, Ω. That is

$$T(t) = \sum_{n=1}^{\infty} T_n e^{in\Omega t} \quad , \tag{55}$$

where

$$T_n = \Omega(2\pi)^{-1} \int_0^{2\pi/\Omega} T(t)\, e^{-in\Omega t}\, dt = T_n^* e^{i\tau_n} \tag{56}$$

is in general a complex quantity with amplitude T_n^* and phase τ_n. In addition to specifying the extent of the sea breeze, L_x, and T(t), it is necessary to specify the other characteristic physical parameters of the sea breeze which include: σ, the Guldberg-Mohn friction parameter; K, the thermal eddy diffusivity; θ_0, the average ground temperature; $\Gamma = (d\theta_0/dz)$, the initial unperturbed temperature gradient; and sin ϕ, where ϕ is the latitude at which the sea breeze is occurring. (A more comprehensive discussion of these physical parameters and their relationship to the overall structure of the sea-breeze circulation is available in Appendix B.)

The expansion of T(t) in a Fourier series results in the following expansion of the components of the wind field:

$$u(x,y,z,t) = \sum u_n(x,y,z,t) \quad , \tag{57}$$

$$v(x,y,z,t) = \sum v_n(x,y,z,t) \quad , \tag{58}$$

and

$$w(x,y,z,t) = \sum w_n(x,y,z,t) \quad , \tag{59}$$

where u_n, v_n, and w_n are the partial contributions to the x, y, and z components of the wind field respectively from the nth harmonic. These quantities are essentially given by Eqs. (B.59), (B.60), and (B.61) of Appendix B, but can be simplified to the following form:

$$w_n = \sin \lambda x J_{nz} \left[e^{k_{n1}z} \cos\left(n\Omega t + \ell_{n1}z + \phi_n\right) - e^{k_{n2}z} \cos\left(n\Omega t + \ell_{n2} + \phi_n\right) \right] , \tag{60}$$

$$u_n = \cos \lambda x J_{nx} \left[\bar{K}_{n1} e^{k_{n1}z} \cos\left(n\Omega t + \ell_{n1}z + \phi_n + \eta_{n1}\right) - \bar{K}_{n2} e^{k_{n2}z} \cos\left(n\Omega t + \ell_{n2}z + \phi_n + \eta_{n2}\right) \right] , \tag{61}$$

and

$$v_n = \cos \lambda x J_{ny} \left[\bar{K}_{n1} e^{k_{n1}z} \cos\left(n\Omega t + \ell_{n1}z + \phi_n + \eta_{n1} + \nu_n\right) - \bar{K}_{n2} e^{k_{n2}z} \cos\left(n\Omega t + \ell_{n2}z + \phi_n + \eta_{n2} + \nu_n\right) \right] . \tag{62}$$

The constants J_{nz}, J_{nx}, and J_{ny} are each proportional to T_n^*, the magnitude of the nth temperature harmonic, and like all the mode-dependent constants appearing in Eqs. (60)-(62) are dependent on the physical parameters of the sea breeze. The constants k_{n1}, ℓ_{n1}, k_{n2}, ℓ_{n2}, $\bar{K}_{n1}$, $\bar{K}_{n2}$, η_{n1}, η_{n2}, and ν_n are completely independent of T_n^* or τ_n, while $\phi_n = \alpha_n + \tau_n$ where α_n is mode-dependent but otherwise independent of T_n^* or τ_n.

Since k_{n1} and k_{n2} are negative, all the components of the sea breeze will decay with altitude. The sea breeze does not have a precisely defined height but an effective height can clearly be related to the exponential decay constant. Because the first harmonic will always be the predominating term, we have decided to define the height of the sea breeze as twice the reciprocal of the minimum of $|k_{11}|$ or $|k_{12}|$. Thus H_s, the height of the sea breeze, is calculated internally and the user need not concern himself with its specification.

It is appreciated that situations can arise where information regarding the internal structure of the predicted sea breeze may be required. For this reason provision has been made to have the program print out the important mode-dependent constants and H_s.

We shall now briefly discuss the availability of the physical parameters of the sea breeze. A summary of suggested parameter values is given in Table 3 (p. 110).

L_x, the total extent of the sea breeze, is twice the inland or seaward extent of the sea breeze (in our sea-breeze model it is assumed that the inland and seaward extent of the sea breeze, as measured from the coastline, are equal). The dimensions of L_x are assumed to be available.

K, the thermal eddy diffusivity, is taken to be a space-independent quantity and as such its precise numerical value is not well defined. Measurements of K can, however, be made, and from them a suitable average value deduced, characteristic of a particular situation.

θ_o, the average ground temperature, can be determined by standard techniques.

Although σ, the Guldberg-Mohn parameter, does describe the effect of viscosity on damping the sea breeze, it is in some respects a device for incorporating friction in a simplified way — the reason being that it leads to relatively simple mathematical descriptions of circulation systems which appear to be in agreement with experiment. By increasing the values of σ we shorten the time lag between the maximum temperature and the maximum wind intensity of the sea breeze and also decrease the intensity per unit of temperature differential. For instance, in calculations performed by Defant,[6] it was shown that holding all other parameters fixed and increasing σ from 0 to 2.5×10^{-4} $\sec^{-1}$ shortened the time lag between maximum temperature differential and the maximum wind velocity from 6.7 to 1.4 hr. Concurrently, for the same temperature differential, a factor of 3 decrease in wind velocity occurred. The value of σ to be used in a given situation must be based upon past observations; that is, the sea-breeze circulation must be matched with the mathematical model by adjustment of σ. There are to our knowledge no known experimental methods which yield σ; however, suggested values are given in Table 3 (p. 110).

Γ, the vertical temperature gradient of the unperturbed atmosphere, is assumed as is done in all models of the sea breeze,to be positive.

T_n^* and τ_n, the amplitude and phases of the temperature harmonics, are input quantities calculated from the following formulas. Defining certain quantities δ_n and Δ_n by the equations

$$\delta_n = (2\pi)^{-1}\,\Omega \int_0^{2\pi/\Omega} T(t)\cos(n\Omega t)\,dt \tag{63}$$

and

$$\Delta_n = (2\pi)^{-1}\,\Omega \int_0^{2\pi/\Omega} T(t)\sin(n\Omega)\,dt\ , \tag{64}$$

where the time integration extends over 24 hr beginning at 1200 (noon) local time, gives

$$T_n^* = \left(\delta_n^2 + \Delta_n^2\right)^{1/2} \tag{65}$$

and

$$\tau_n = \tan^{-1}\left(\Delta_n/\delta_n\right)\ . \tag{66}$$

It is assumed that the meteorologist who is using the sea-breeze program can identify those measurements which can lead to the designation of the temporal behavior of the temporal differential T(t). It should be understood that the time, t, used in the sea-breeze calculations is always relative to local noon time.

Besides the inherent physical parameters just described, there is one other parameter, related to the compatibility of the geometric description of the sea-breeze coastline to the computer program grid structure requirements, which must be discussed. It is anticipated that in any real situation a well-defined coastline length L_y will exist for the sea breeze. Thus, L_x, L_y, and ψ, the angle describing the orientation of the sea-breeze coastline with respect to the y-grid axis, Y_g, establish the horizontal configuration of the sea breeze.

For computational purposes it is necessary to render the sea-breeze geometry compatible with the (X_g, Y_g) grid structure. This necessitates redefining the extent of the sea breeze over the area bounded by the dashed lines (in Figure 12) with maximum and minimum values given by Y_{max}, Y_{min}, X_{max}, and X_{min}, which are determined by establishing the geometric center of the sea breeze, L_x, L_y, and ψ. However, the calculated values of the wind field are strictly defined over the domain of sea breeze as determined by L_x and L_y and x-y coordinate system. Thus, we must extrapolate the calculations into the stipled and hatched areas. Since the shoreline is assumed infinite in extent, it is theoretically permissible to use the calculated results, as they are, to determine the wind field in the stipled area. On the other hand, the extrapolation of the results for values of $|x| > (L_x/2)$ is not immediately obvious, but nevertheless can be achieved by interpreting the sea breeze as a circulation cell located in a continuous chain of circulation cells. However, this is only an approximation, arising from lack of a better method for attacking the problem. The degree to which this approximation may be meaningful is unresolved, although there is evidence to suggest that compensating air currents flow in regions adjacent to the sea breeze. If the sea breeze were really a single cell in a chain of circulating cells, then the sea-breeze equations as already derived would suffice to determine the wind field beyond $|x| > (L_x/2)$ because of the x periodicity of the system. To incorporate the idea of the circulation cells, and at the same time provide enough flexibility to account for departures from the idealiztion, we have decided to define the wind field in the hatched region by the relationship

$$\underset{\sim}{V}(x, y, z, t) = \underset{\sim}{V}_c(x, y, z, t) \exp \left\{ -k_a \left[|x| - \left(L_x/2 \right) \right] \right\} ,$$

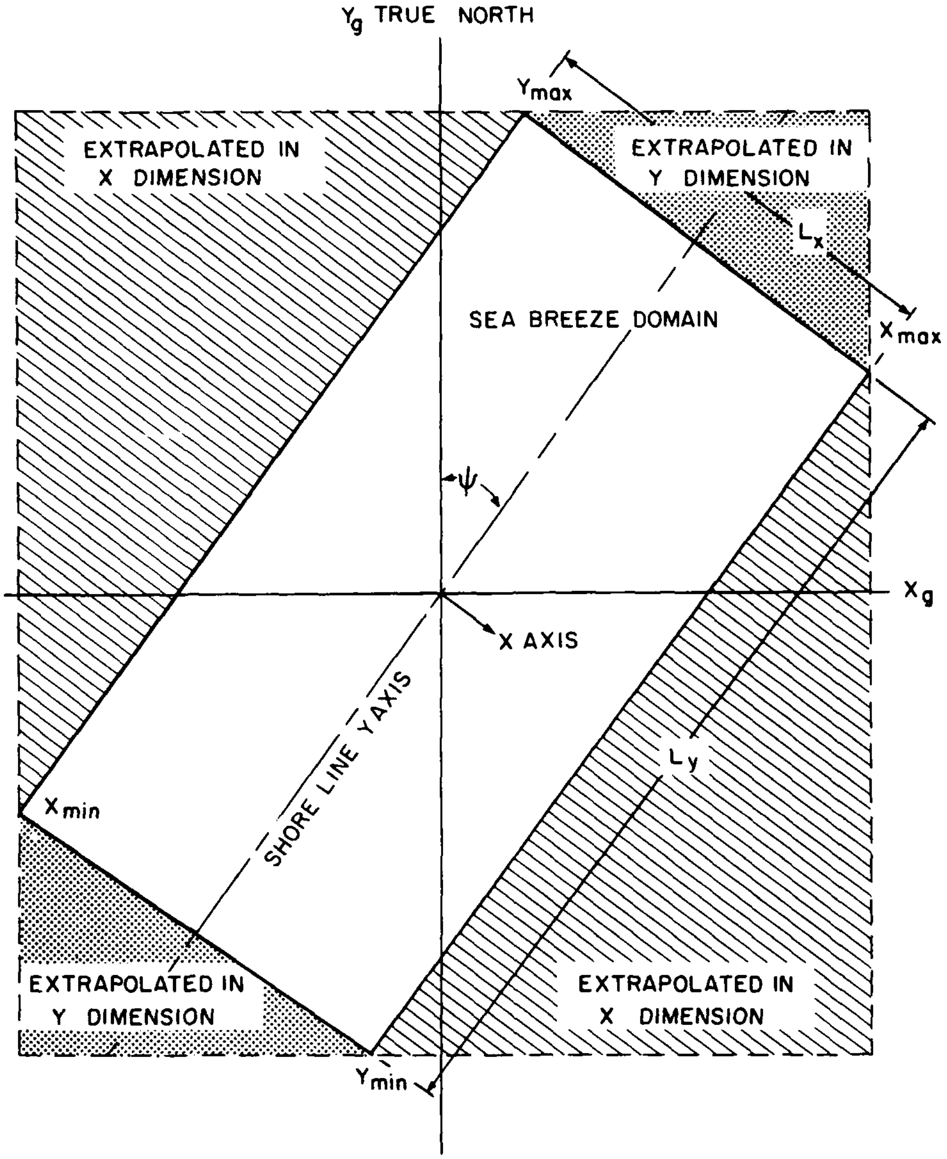

Y_g TRUE NORTH
Y_{max}
EXTRAPOLATED IN X DIMENSION
EXTRAPOLATED IN Y DIMENSION
L_x
X_{max}
SEA BREEZE DOMAIN
ψ
X_g
X AXIS
SHORE LINE Y AXIS
L_y
X_{min}
EXTRAPOLATED IN Y DIMENSION
EXTRAPOLATED IN X DIMENSION
Y_{min}

Figure 12. Geometric Considerations Related to the Sea Breeze

where $\underset{\sim}{V}_c$ is the calculated wind field in vector form whose x, y, and z components are given by Eqs. (60)-(62), and k_a is an attenuation factor. The case $k_a = 0$ corresponds to the idealized circulation cell system, whereas large values of k_a correspond to attenuated adjacent circulation cells. The computer program is constructed so that the present method of extrapolation can be changed at a later date. k_a is an input parameter which must be specified by the user.

Transport in a Macrowind Cell

Particle velocity for all particle transport is assumed to be given by the wind velocity (three dimensional) at the particle position minus the still-air particle settling rate. Within macrocells, particle trajectories are taken as straight lines; therefore, particles can be moved from one boundary to the next in one computational step. Such boundary-to-boundary transport is illustrated in two dimensions in Figure 13, which also shows the boundaries of one local cell superimposed on the macrostructure. In more detail, when a particle intercepts the boundary of a macrocell, the computations proceed as follows. We obtain the particle velocity components normal to the boundary planes of the wind cell. We then compute the time at which a boundary intercept would occur in each of the (three) component directions. The earliest of these (three) intercepts indicates the time of exit and the coordinates of the exit point are computed. Transport of a single particle

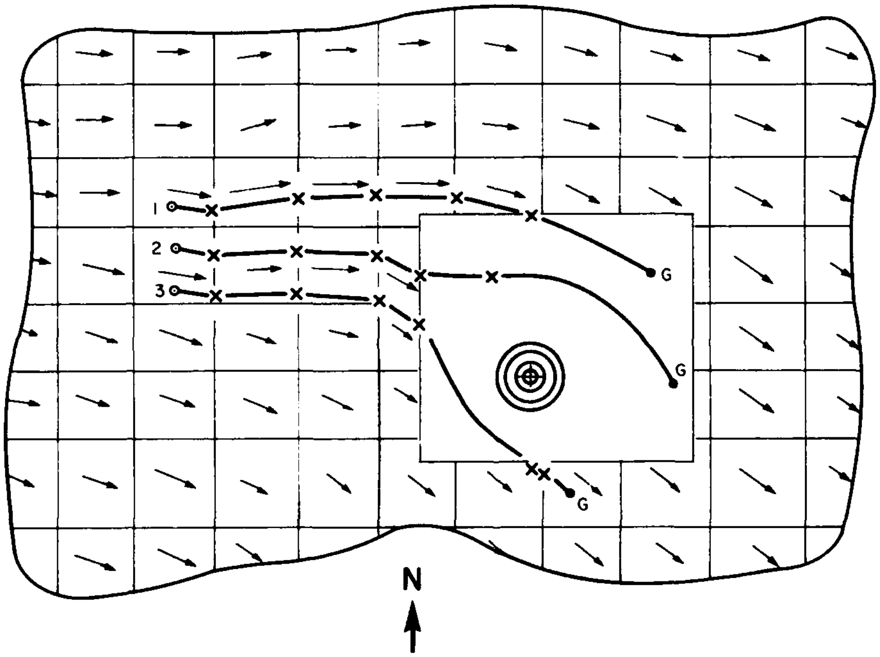


Figure 13. Boundary-to-Boundary Transport and a Mountain Wind Cell

through the compartmented macrowind field is merely an iteration on this s'ngle particle — single cell logic. During a calculation, complete trajectories are computed serially for individual particles between major time, or topography boundaries, or both. The exact natures of these boundaries are discussed later.

Transport in a Local Circulation System

When a particle passes into a local circulation system cell the mode of trajectory calculation changes from that used in the macrowind-field cells. Within local circulation system cells it is possible to calculate unique wind field velocities at all points. For this reason particle trajectories are computed from the particle velocity equations using point-slope numerical integration with a constant time step. The method is as follows. Suppose after n time steps the particle is at location (x_n, y_n, z_n) and has velocity $(v_{x,n}, v_{y,n}, v_{z,n})$. Then to determine the position of the particles at the n + 1th time step, for example, in the x direction, we perform the computation $x_{n+1} = x_n + v_{x,n}\Delta t$ (it is repeated for the other directions). The magnitude of Δt is determined by the user. The point-slope method of integration, including restriction on values of Δt, is discussed by Milne.[7]

Temporal Variation of the Wind Field

Temporal variation of the wind field is achieved by periodically replacing the entire wind field description data set. The period of data replacement is variable and each replacement interval is specified by the user.

Topography Description

Three different methods of specification are available. First, the user can specify a planar deposition surface at any altitude for use in areas not covered by local circulation cells. Alternatively, a system has been provided to allow the user to specify the topography in a piecewise-planar manner such as that illustrated in Figure 14. A grid system that can be subdivided indefinitely to yield any desired resolution of detail is used to achieve the desired resolution without the excessive redundancy of a strictly regular grid. Within local circulation cells other topographic descriptions must be used. For instance, the topography of mountains

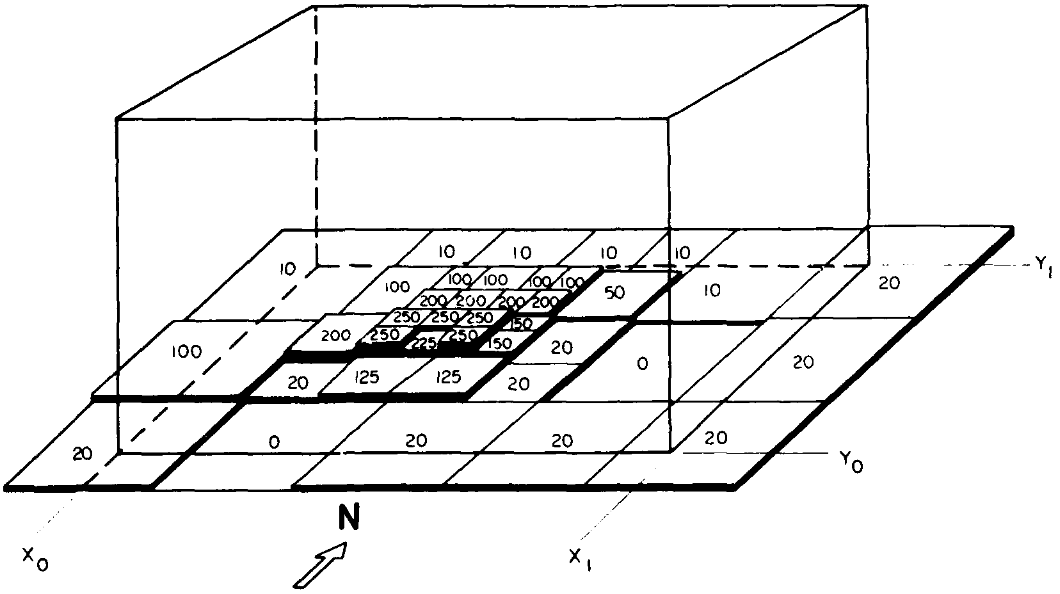


Figure 14. Piecewise-Planar Topography Specification Below the Macrowind-Field Volume (numbers are surface heights; vertical scale is exaggerated)

covered by a mountain wind model ce.i is described by an analytical mountain shape function. There is no provision in the model to account for shielding effects of highly variable terrain. Additional details are given in the User Information section (p. 133 ff) and in Appendix C.

COMPUTER PROGRAM OUTLINE

Description

In its initial form the DELFIC system is designed for execution on the IBM 7094 computer via the IBSYS-IBJOB processor, and the "overlay" feature is used to control the input sequence of major sections of the system. To facilitate discussions of the programs, we have assigned the executive programs of each major section the names LINK1, LINK2, ... , which are more-or-less indicative of their positions in the computation flow sequence. The Transport Module essentially consists of three such major program sections:

LINK5	Initialization and control
LINK6	Wind-field description
LINK7	Particle transport.

Figure 15 shows the arrangement in which the computa ions required during the transport period are grouped for execution. Note that final exit from LINK5, the transport executive, is made to a program called LINK8 — the output processor. Figure 16(a) is a flow chart of the general program logic of the Transport Module. This simplified representation shows in some detail the hierarchy of computation loops that make up the transport logic. A simpler representation of this hierarchy is given in (b) of Figure 16, which shows a nested set of five loops. In the outermost loop, there is a test to determine if the specified temporal extent of the transport has been achieved; if not, an updated version of the wind-field description is computed. In the next lower hierarchy level a part of a multipart wind field description is brought into the computer (if a multipart description is in use) in order to transport particles which have gone beyond the in-core part of the description. In the third level of the hierarchy the topographic description is treated like the multipart wind description (if required). In the particles aloft list loop individual particle descriptions are given sequential attention, and in the actual transport code the individual fallout particle is transported until it reaches either the ground or some boundary at which in-core data are insufficient to move it further.

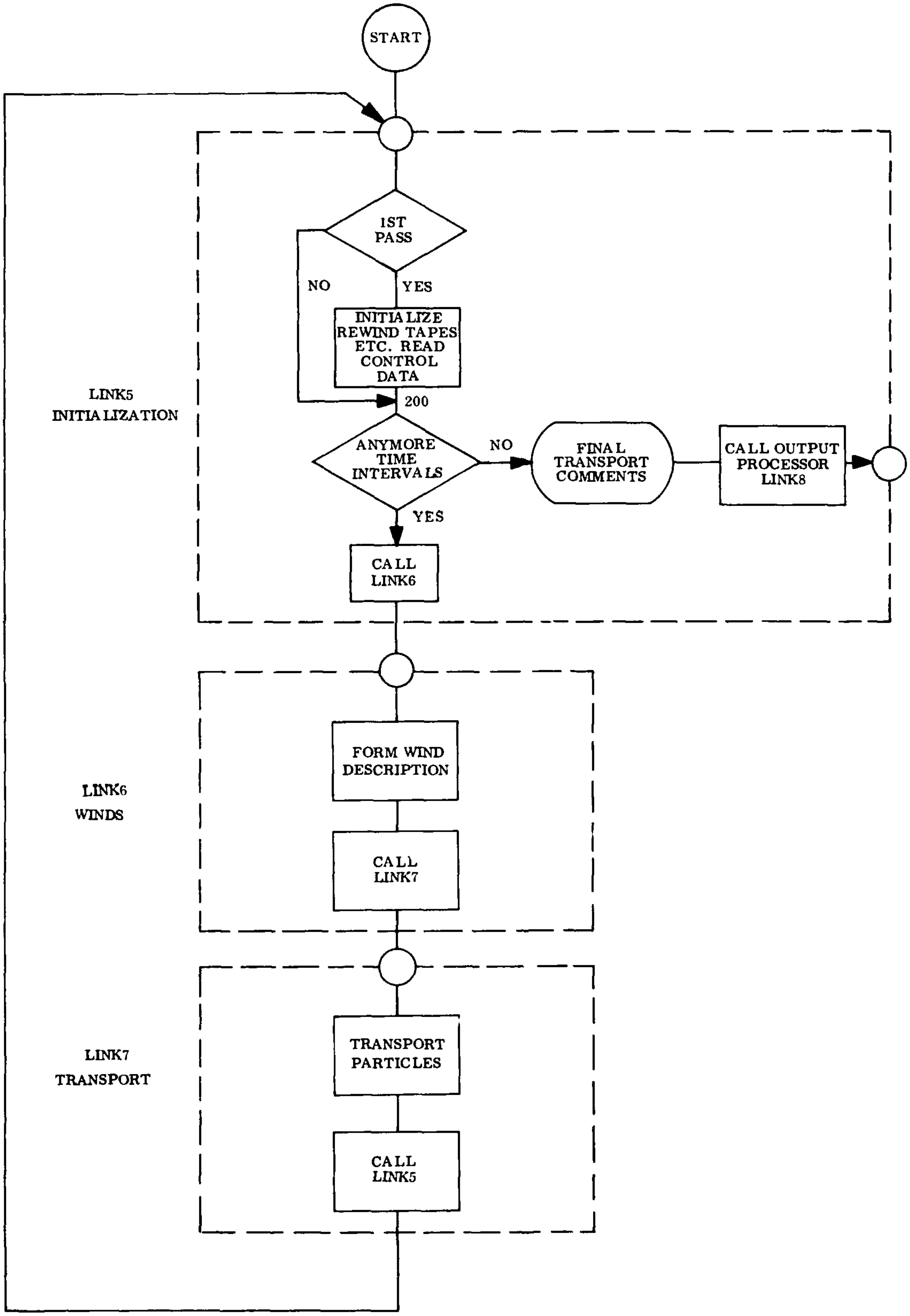


Figure 15. Program Arrangement for the Transport Module

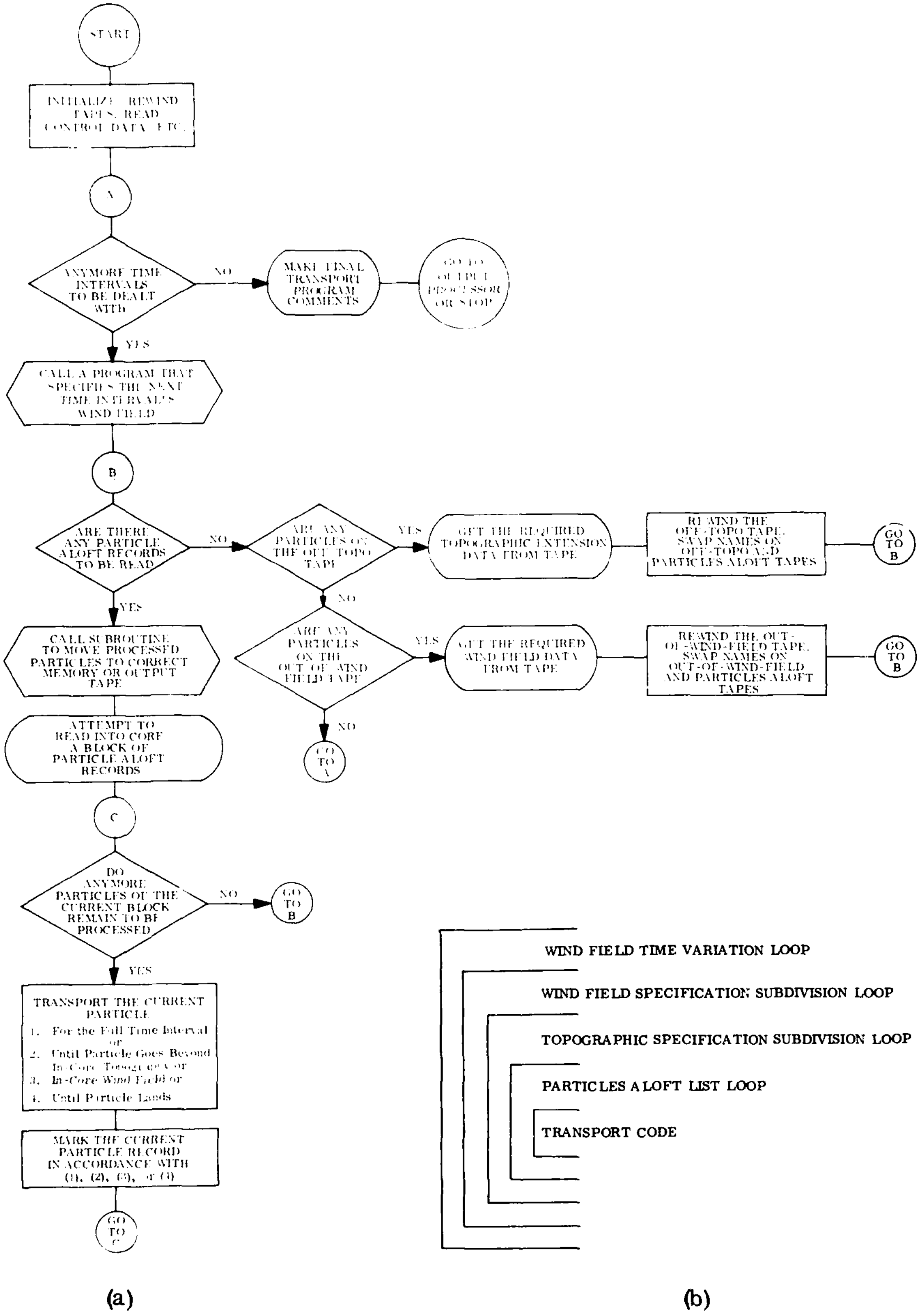

START
INITIALIZE REWIND TAPES, READ CONTROL DATA ETC.
A
ANYMORE TIME INTERVALS TO BE DEALT WITH
NO
MAKE FINAL TRANSPORT PROGRAM COMMENTS
GO TO OUTPUT PROCESSOR OR STOP
YES
CALL A PROGRAM THAT SPECIFIES THE NEXT TIME INTERVAL'S WIND FIELD
B
ARE THERE ANY PARTICLE ALOFT RECORDS TO BE READ
NO
ARE ANY PARTICLES ON THE OFF TOPO TAPE
YES
GET THE REQUIRED TOPOGRAPHIC EXTENSION DATA FROM TAPE
REWIND THE OFF-TOPO TAPE, SWAP NAMES ON OFF-TOPO AND PARTICLES ALOFT TAPES
GO TO B
NO
ARE ANY PARTICLES ON THE OUT OF WIND FIELD TAPE
YES
GET THE REQUIRED WIND FIELD DATA FROM TAPE
REWIND THE OUT-OF-WIND-FIELD TAPE, SWAP NAMES ON OUT-OF-WIND-FIELD AND PARTICLES ALOFT TAPES
GO TO B
NO
GO TO A
YES
CALL SUBROUTINE TO MOVE PROCESSED PARTICLES TO CORRECT MEMORY OR OUTPUT TAPE
ATTEMPT TO READ INTO CORE A BLOCK OF PARTICLE ALOFT RECORDS
C
DO ANYMORE PARTICLES OF THE CURRENT BLOCK REMAIN TO BE PROCESSED
NO
GO TO B
YES
TRANSPORT THE CURRENT PARTICLE
1. For the Full Time Interval or
2. Until Particle Goes Beyond In-Core Topography or
3. In-Core Wind Field or
4. Until Particle Lands
MARK THE CURRENT PARTICLE RECORD IN ACCORDANCE WITH (1), (2), (3), or (4)
GO TO C
WIND FIELD TIME VARIATION LOOP
WIND FIELD SPECIFICATION SUBDIVISION LOOP
TOPOGRAPHIC SPECIFICATION SUBDIVISION LOOP
PARTICLES ALOFT LIST LOOP
TRANSPORT CODE
(a)
(b)

Figure 16. General Flow Chart of the Transport Module (a), and Transport Module Loops (b)

Figure 17 represents schematically the flow of information from secondary (tape) memory to primary (core) memory and back during an extensive run of the transport program. Using Figure 17 as a guide, let us consider the sequence of data flows.

Initially, only the particles (input) and topography tapes contain any information, and only the transport codes themselves are in primary memory. The initialization and control program (LINK5) reads identification information from the particles (input) tape, writes comments on the system output tape, and then, if required, loads the topography arrays from a previously prepared topography tape.* At this point the wind-field description program (LINK6) is called and a wind-field description is generated. This description is generated directly (and completely) into the wind arrays in primary memory by the current versions of LINK6. However, if future requirements warrant, a modified version of LINK6 can produce a more extensive description of the wind field and be forced to store part of it on tape. In either case, when LINK6 is completed, the wind arrays are loaded and a "map" of the wind tape (if any) has been produced and stored in primary memory.

Next, we enter LINK7, the actual transport program, and read a part of the particles (input) tape into primary memory. The particle descriptions are then transported one at a time until one of five possible conditions arises. These conditions, which may be thought of as boundaries, are.

1 The particle drifts beyond the area for which a topographic height has been specified in core. In this case the particle's description is marked so that it will be eventually written onto the off-topo tape

2. The particle drifts beyond the region for which the wind velocity field has been specified in core. In this case the description is marked to go on the out-of-wind-field tape.

*A special program has been written to aid the researcher in preparing topography tapes from topographic maps or other sources (see Appendix C). The user may, however specify a planar topography and bypass the use of a detailed topographic tape.

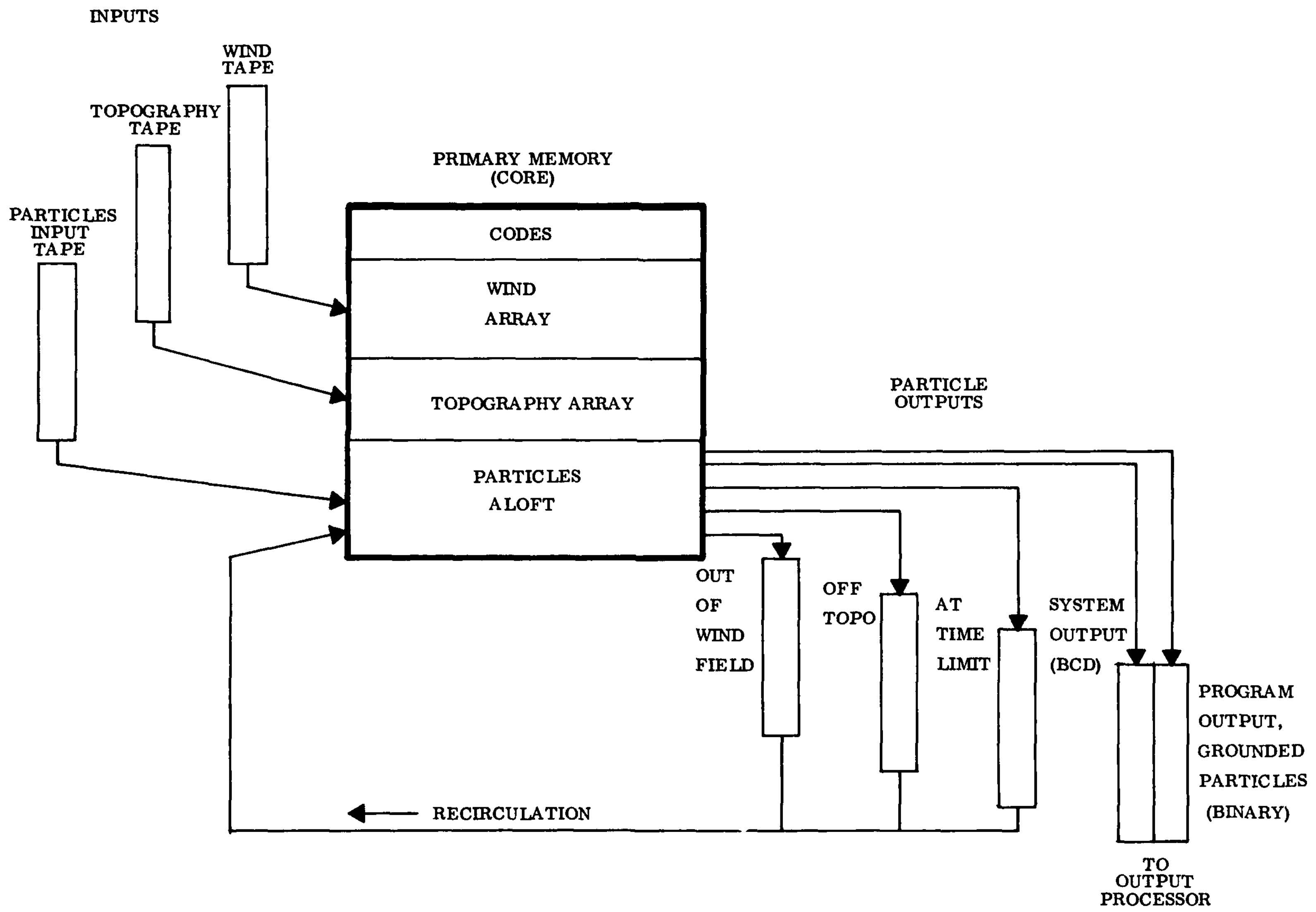


Figure 17. Transport Module Data Flow

3. The particle encounters neither of the previously mentioned boundaries and is still aloft at the time when the wind-field description must be updated to achieve discrete temporal variability of the wind field. In this case the description is marked to go on the time boundary tape.

4. The particle becomes grounded on the topography. In this case the particle description is marked so that it eventually is written on the program output tape which is used as an input to the output processor.

5. The particle drifts beyond the entire secondary as well as primary memory region of specification for either topography or winds In this case the particle is labeled as a "lost particle" and it is removed from the transport process.

When the entire block of descriptions has been read into memory and processed the next block of particle descriptions is read into memory and processed. After all particle descriptions on the original input tape have been processed treatment of the data (if any) on the three recirculation tapes begins. First, if any descriptions were written on the off-topo tape, a new block of topographic data is read in and the off-topo tape is put into the position (symbolically) of the original particles input tape. Processing continues as before, and eventually the condition will obtain that at the end of a pass no descriptions will be found on the off-topo tape Under this condition we next consider the out-of-wind-field tape in a manner analogous to "off-topo." The treatment given to the time boundary tape is similar, but when all particles that are still aloft are on the time boundary tape, a new description of the wind field must be computed. Before each call of the wind-field program (LINK6) a check is made to see if the transport time limit has been exceeded, and if it has been, a termination procedure is executed to record the final status of memory.

Table 1 is a summary of the 14 programs of the Transport Module. Detailed discussions of these programs are given in the next section.

TABLE 1

A SYNOPSIS OF THE PROGRAMS OF THE TRANSPORT MODULE

Name	Called By	Purpose
LINK5	Executive Program M3*	Transport initialization and control.
RDTOPO	LINK5 and LINK7	Reads a block of topographic data into core memory.
LINK6	Executive Program M3*	Calls subroutine MKWIND
DUMPP	LINK5 and LINK7	Makes room in the particle array for a block of N new particle descriptions by writing a set of particle descriptions onto some memory or output tape.
MKWIND	LINK5	Updates entire wind field description directly into the common wind field arrays of the Transport Module. It accepts many wind vector data and computes a spatially variant wind field description by a number of different methods such as: 1. Assign to the wind grid point the vector at the nearest data points 2. Assign to the wind grid point a distance weighted average of the vectors at the N nearest data points 3. Fit a linear model to the N nearest data points by least squares and use that model to assign the vector to the grid point Provision has been made throughout the programming for the eventual inclusion of a system for the use of a voluminous wind field description recorded on and retrieved from a secondary memory system such as magnetic tape or disk.
RDCIRS	MKWIND	Reads data which describe any local circulation system which may exist. These data state the size and location of each local circulation cell and identify the computation program which is to be used within each cell.
LINK7	Executive Program M3	Transports all input particle descriptions through the specified wind field.
FALRAT	LINK7	Computes settling rate for a particle as a function of particle size and altitude.
HEIGHT	LINK7	Retrieves the height of the topography for the position of the current particle from the topographic data arrays.
LOTRAN	LINK7	Transports a particle within or above a local circulation system cell.
MTWND1	LINK7 and LOTRAN	A dual purpose subroutine which (1) reads the data that is needed by the MTWND1 (mountain wind) program and carries out those computations that are invariant with position, or (2) computes wind vectors at specified positions within the MTWND1 cell.
RGWND1	LINK7 and LOTRAN	Like MTWND1 but for the analytical ridge wind model.
CBREZ1	LINK7 and LOTRAN	Like MTWND1 but for the analytical sea breeze wind model.
GETWND	LINK7 and LOTRAN	Retrieves the appropriate wind vectors from the macro-wind-field description arrays.

*See DASA-1800-VII (Operator's Manual).

Program Discussion

In this section we present a detailed description of each of the executive programs and subroutines[*] of the Transport Module Each program description is headed by the program name, its call list (if any), and flow chart (FC) number.

Subroutine FALRAT (ALT, PSIZE, FV, ATEMP, RHO. FROG, ISOUT)(FC-1)

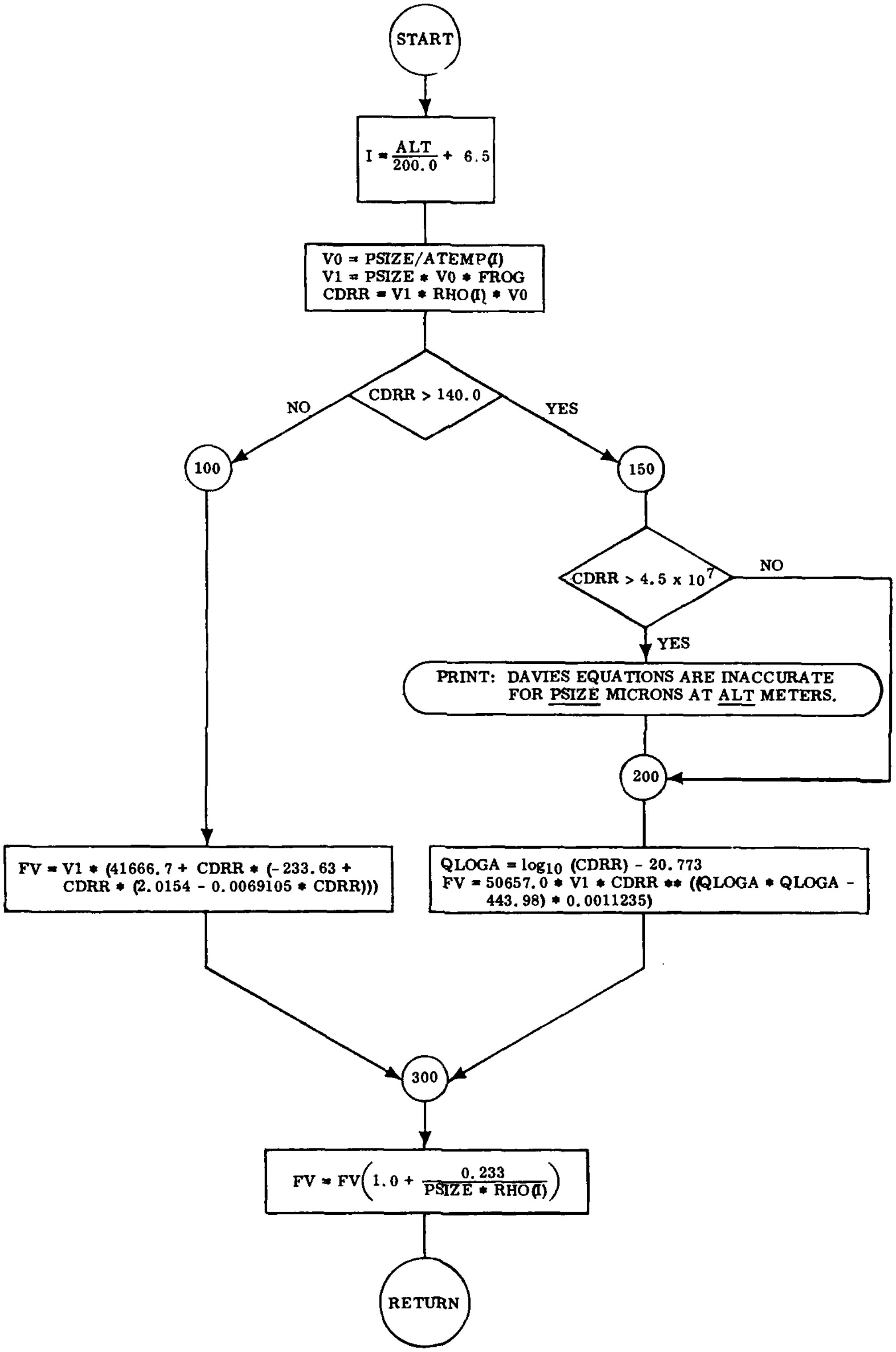
This subroutine computes the settling rate of a particle at height ALT in an atmosphere for which the density and dynamic viscosity are tabulated in arrays RHO and ATEMP respectively. These tabulations must be for 200 m intervals starting from 1000 m below MSL.[†] Fall rate equations derived by Davies[2] are used All units are in the meter-kilogram-second (mks) system except for PSIZE, the diameter of the particle, which is in microns, and FROG, which is the pre-computed product $4/3*g*ROPART*10^{-8}$ where ROPART is the density of fallout particles (mks) and g is the acceleration of gravity (mks).

The Davies equations which are functions of the quantity C_DR^2 are valid over separate ranges of C_DR^2. The separation occurs at $C_DR^2 = 140$. An overall upper limit of $C_DR^2 = 4.7 \times 10^7$ is imposed by Davies for the validity of his equations. However, for lack of an appropriate substitute for use in computing the settling rate for particles which exceed this limit, we have chosen to use Davies equation for cases where $C_DR^2 > 4.7 \times 10^7$. The program will record an indication that the limit was exceeded for each case encountered

The computation proceeds in the following manner. After locating the particle in one of the atmospheric layers,[†] the program computes CDRR(C_DR^2) and several intermediate parameters Next CDRR is tested to determine which expression is to be used for the terminal velocity. If the upper range is used, a check is made to determine if CDRR > 4.7×10^7. If this is so, the printout "DAVIES EQUATIONS ARE INACCURATE FOR PSIZE MICRONS AT ALT METERS" is made. PSIZE refers to particle diameter in microns and ALT refers to particle altitude in meters Then, the settling rate of the particle, FV, is computed Finally, a drag slip correction in the form of Cunningham's factor (see Appendix B of Ref 1) is applied to FV and control is returned to the calling program.

[*] There are numerous error checks throughout the programs that result in calls to subroutine ERROR when termination is required A full description of subroutine ERROR is included in DASA-1800-VII (Operator's Manual)

[†] The atmosphere structure defined for the cloud-rise computations is used


START
I = ALT/200.0 + 6.5
V0 = PSIZE/ATEMP(I)
V1 = PSIZE * V0 * FROG
CDRR = V1 * RHO(I) * V0
CDRR > 140.0
NO
YES
100
150
CDRR > 4.5 x 10^7
NO
YES
PRINT: DAVIES EQUATIONS ARE INACCURATE FOR PSIZE MICRONS AT ALT METERS.
200
FV = V1 * (41666.7 + CDRR * (-233.63 + CDRR * (2.0154 - 0.0069105 * CDRR)))
QLOGA = log10 (CDRR) - 20.773
FV = 50657.0 * V1 * CDRR ** ((QLOGA * QLOGA - 443.98) * 0.0011235)
300
FV = FV(1.0 + 0.233/(PSIZE * RHO(I)))
RETURN

FC-1. Flow Chart for Subroutine FALRAT

Subroutine DUMPP (FC-2 and FC-3)

This subroutine along with parts of the main programs of LINK5 and LINK7 manages the system of primary (core) and secondary (tape) memory that is used to record descriptions of particles (central particles of cloud subdivisions) during transport. DUMPP serves to select and write one or more of the subsets of the particle descriptions (defined in Table 2) in primary memory onto some secondary memory or output tape and thus to make room available in primary memory. As one of its inputs DUMPP accepts the number (N) of particle descriptions for which room must be prepared in primary memory. It does not return until at least N blank lines have been made available in the top (low-numbered end) of the particle description arrays. DUMPP begins by selecting for dumping onto tape that set of particles which is considered best from the point of view of machine efficiency. In general, the largest set is considered to be best to dump because of the time required to put a tape drive into motion. However, an exception is made for the class of grounded particles, since they will be written on the transport-output tape (IPOUT) and will never be recirculated into the primary memory; therefore, whenever dumping the set of grounded particles would make sufficient room available (counting those lines that are already blank) for N incoming particle descriptions, the set of grounded particles is dumped. Before the actual dumping occurs, the particle description in core storage is reordered so that all descriptions to be dumped are located in a solid block beginning at the top of the particle descriptions array, and all particle descriptions that are to remain in core are moved below this block. The dumping operation then is executed, and finally a block of blanks (empty spaces) large enough to receive the incoming particles is prepared at the top of the particle descriptions array.

The main transport loop (in LINK7) passes sequentially across the list of particle descriptions which consist, for the Jth particle, of three spatial coordinates XP(J), YP(J), and ZP(J); a time coordinate TP(J); a particle size PS(J); and a mass per unit area FMAS(J). At the end of its pass the main transport will have marked each of the descriptions to indicate its membership in one of the five classes listed in Table 2. To avoid the use of another array of data, the sign bit of FMAS(J) and the sign and magnitude of the time coordinate TP(J) are used to record the class of the description as indicated in Table 2.

TABLE 2

PARTICLE CLASSIFICATION IDENTIFIERS USED BY DUMPP

Class	FMAS(J)	TP(J)	JTEST1
Blank	0	Not Used	
Grounded particles	-FMAS(J)	-TP(J)	1
Lost particles. These are particles that have gone beyond the complete wind field or topographic description	-FMAS(J)	TLIMIT	2
Topography boundary particles. These are particles at the limit of the in-core topography	+FMAS(J)	-TP(J)	3
Time boundary particles. These are particles at the time limit for the in-core wind field	+FMAS(J)	ENDTIM	4
Wind-field boundary particles. These are particles at the spatial limit of the in-core wind field	-FMAS(J)	+TP(J)	5

Referring to the general and the deailed flow charts of subroutine DUMPP (FC-2, and FC-3, respectively), we shall next consider its operation. First by comparing N, the number of incoming particle descriptions, with NFREE, the current number of blank lines in the arrays, we can immediately determine whether any descriptions must be dumped. If none need be dumped, we set JTEST = 0 to indicate that no blanks are known to already be at the top of the particle arrays and then transfer to 152 where the needed number of blank lines are brought to the top of the arrays from wherever they may be within them. If some particles must be dumped, we transfer to 151 to determine which set to dump.

At 151 we determine if the number of particles in the grounded set plus the number of blank lines in total provide enough space for the block of N particles which are to come in. If they do, we set the parameters JTEST = 1 and JTEST = NG to indicate respectively the class of particles to be dumped and the size of that class. Then a transfer is made to 18 where other preparations are made to carry out the dump. If a larger dump is required to yield N empty spaces, the set with the largest membership is selected and JTEST1 (see Table 2) and JTEST are set appropriately.

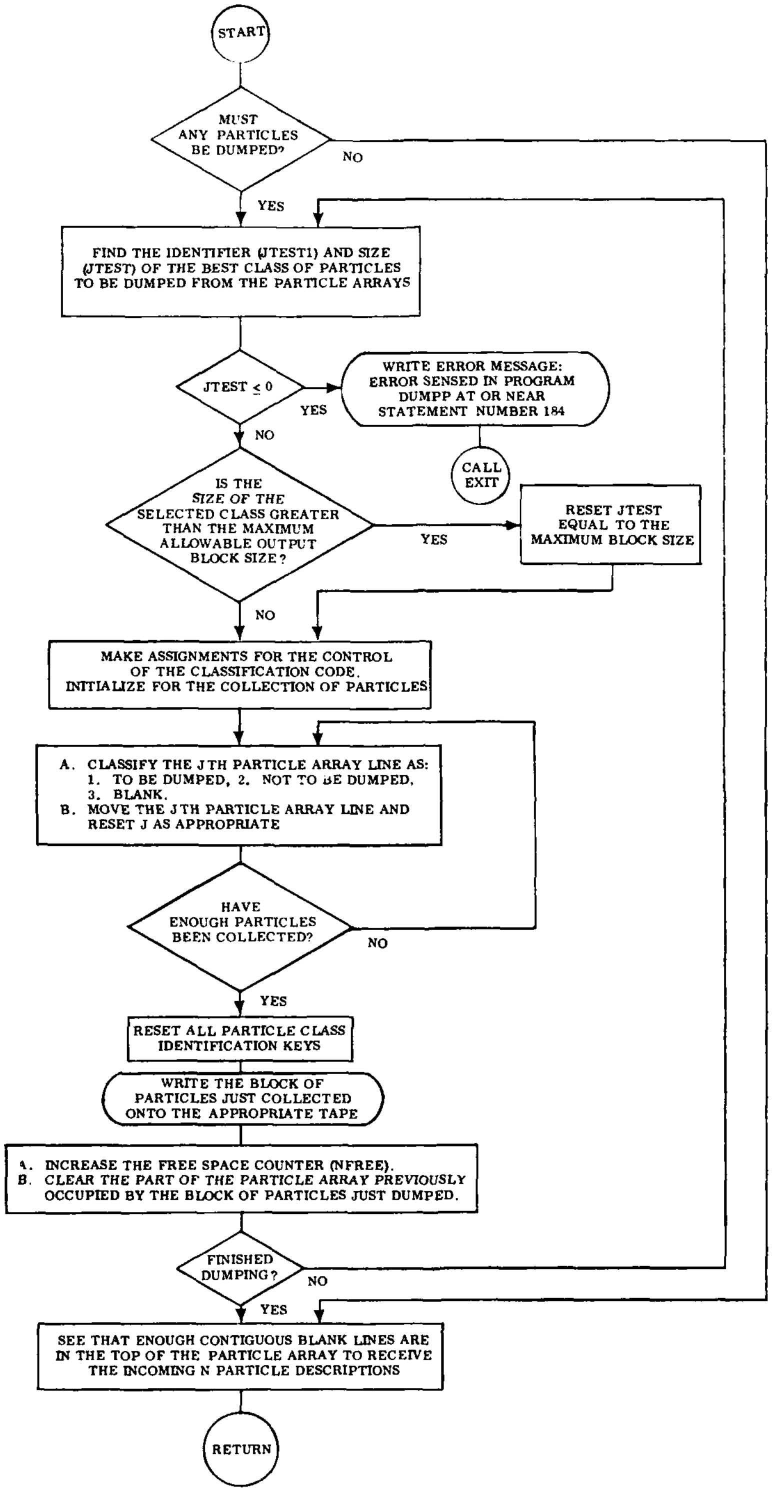
At 18 a safety test leading to an error stop is carried out followed by a threshold test on the size of the set to be dumped. Because a limit exists on the size of any particle block read by the output processor (see DASA-1800-VI), and also because we must impose block size control to allow for recirculation of data during transport itself, a maximum block size is defined within the LINK5 program. No block larger than NBMAX will be written by DUMPP.

At 181 the program branches, on the basis of the class of particles to be dumped (JTEST1), to a code that appropriately sets a group of assigned go-to statements and tape name parameters for use within the code that actually selects particle descriptions. Also at these points, the appropriate class count (NG, NLOST, NTO, NTI, or NW) is decreased in accordance with the number of descriptions about to be dumped.

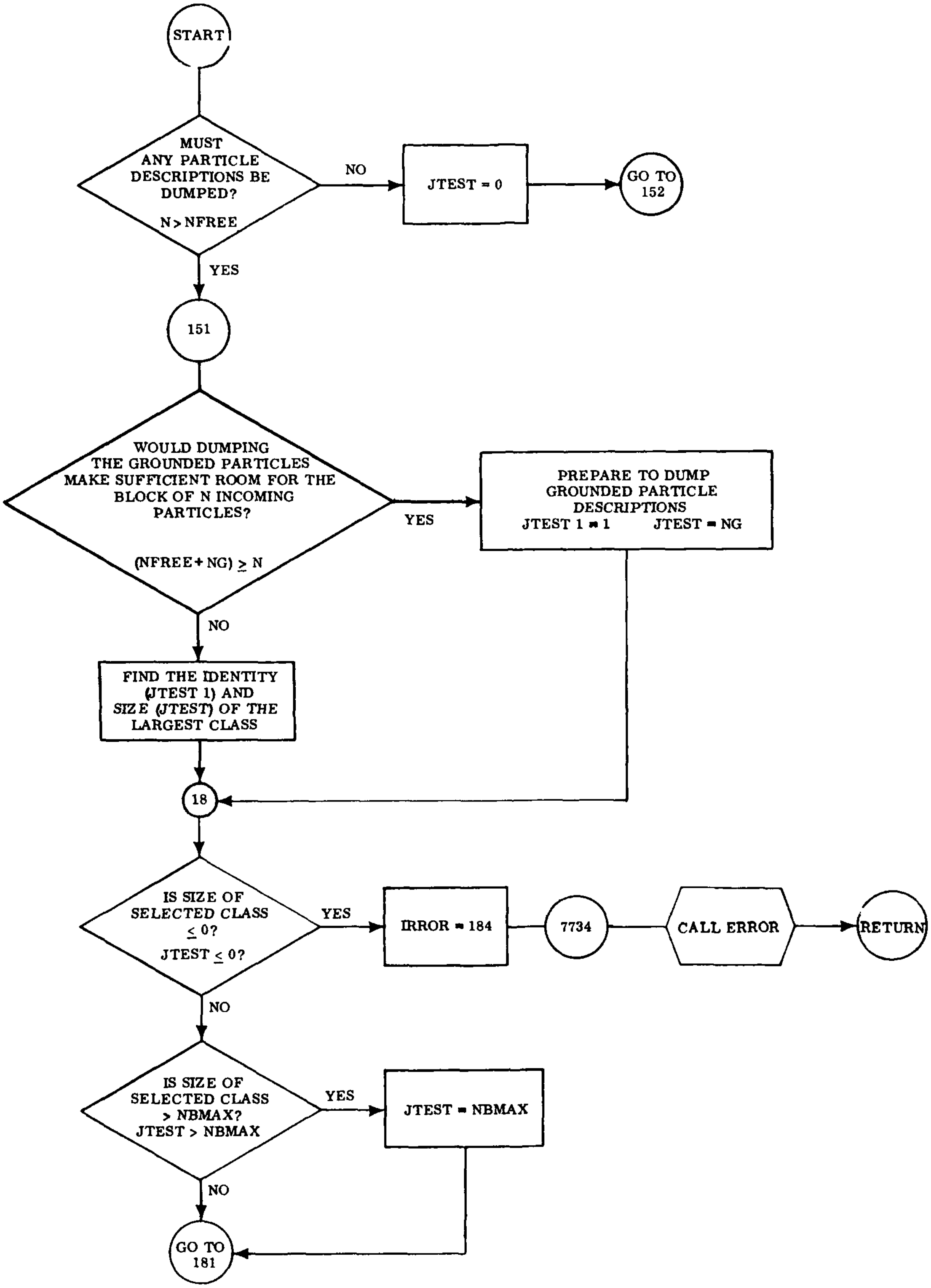
At 99 a one-line summary printout of information on the particle block to be dumped and of the particle counts is executed. Specifically this output consists of the following data in order of printing from left to right: JTEST, JTEST1, and the current (predump) values of the in-core counts for blanks, grounded particles, lost particles, topography boundary particles, time boundary particles, and windfield boundary particles. Then we set certain parameters that are used within the loop that actually sorts the particles to be dumped into the top of the particles array. That loop, beginning at 98, first classifies a line in the particle array into one of three classes: blank, to be dumped or not to be dumped Classification is done by a set of assigned go-to statements. After this three-way classification, various actions occur in such a way to provide the needed sort into a contiguous block with something close to the theoretically minimum number of word movements. The particle classification and sorting code is logically complex and should be modified only with great caution.

At 1102 the sort is completed and all class indicator signs are set positive in preparation for actual dumping. In the case that lost particles are to be dumped, the control parameter IC(8) is tested to determine if printed listings of lost particles are requested. If IC(8) = 0, the lost particle count and particle descriptions (XP, YP, ZP, TP, PS, and FMAS) for the complete block are written on the IBSYS output tape for printing. If IC(8) ≠ 0, this printing is deleted In any case, no further dumping action is required for lost particles. For all other classifications of particles, the block of particle descriptions is written on the appropriate binary auxiliary tape following its block count.

At 154 additional sorting is done, if necessary, to prepare a solid block of blanks at the top of the particles description array that is large enough to receive the incoming block of particle descriptions This is done by interchanging locations of particles that lie above the block boundary with blanks that lie below it.

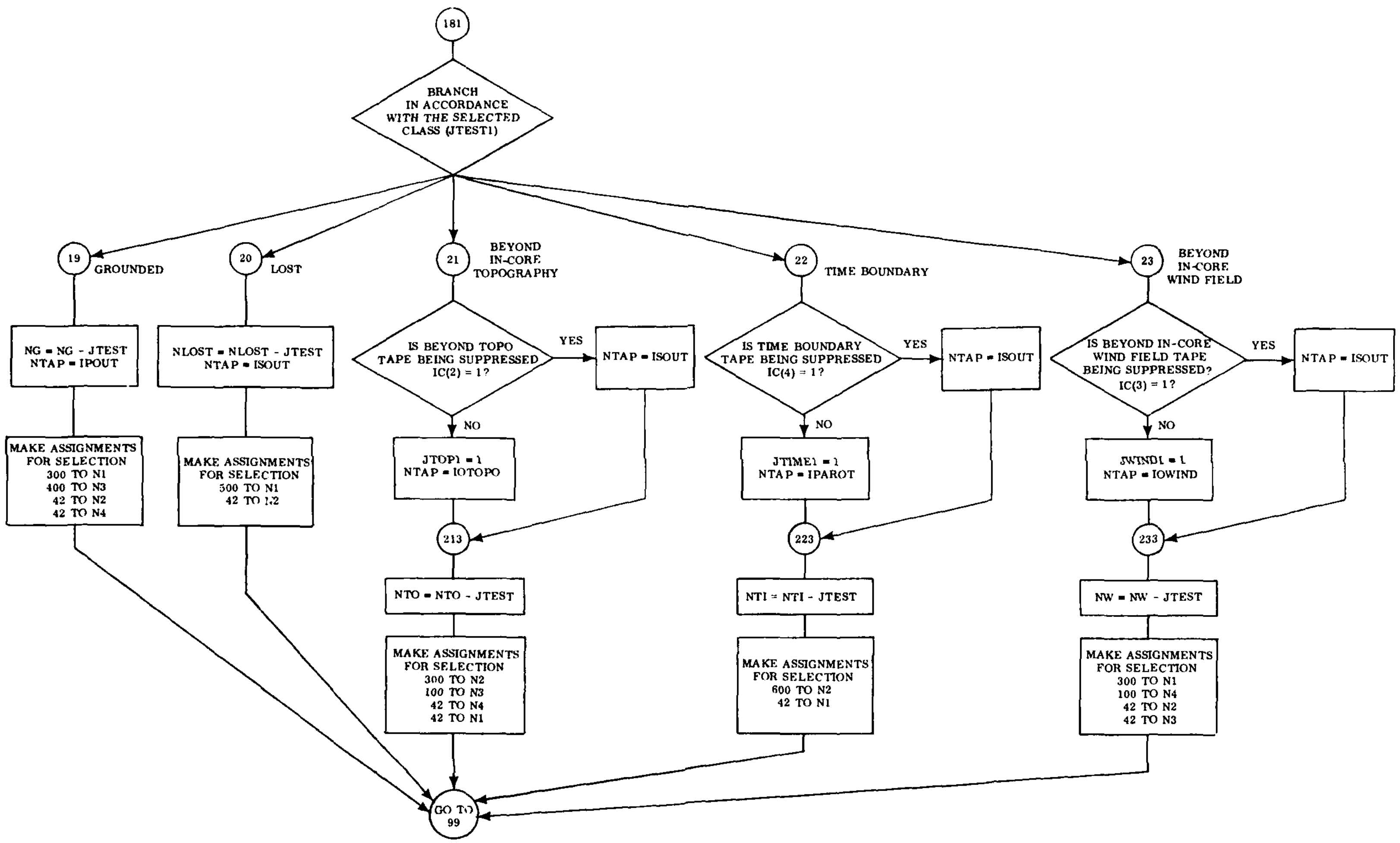

START
MUST ANY PARTICLES BE DUMPED?
NO
YES
FIND THE IDENTIFIER (JTEST1) AND SIZE (JTEST) OF THE BEST CLASS OF PARTICLES TO BE DUMPED FROM THE PARTICLE ARRAYS
JTEST ≤ 0
YES
WRITE ERROR MESSAGE: ERROR SENSED IN PROGRAM DUMPP AT OR NEAR STATEMENT NUMBER 184
CALL EXIT
NO
IS THE SIZE OF THE SELECTED CLASS GREATER THAN THE MAXIMUM ALLOWABLE OUTPUT BLOCK SIZE?
YES
RESET JTEST EQUAL TO THE MAXIMUM BLOCK SIZE
NO
MAKE ASSIGNMENTS FOR THE CONTROL OF THE CLASSIFICATION CODE. INITIALIZE FOR THE COLLECTION OF PARTICLES
A. CLASSIFY THE JTH PARTICLE ARRAY LINE AS: 1. TO BE DUMPED, 2. NOT TO BE DUMPED, 3. BLANK.
B. MOVE THE JTH PARTICLE ARRAY LINE AND RESET J AS APPROPRIATE
HAVE ENOUGH PARTICLES BEEN COLLECTED?
NO
YES
RESET ALL PARTICLE CLASS IDENTIFICATION KEYS
WRITE THE BLOCK OF PARTICLES JUST COLLECTED ONTO THE APPROPRIATE TAPE
A. INCREASE THE FREE SPACE COUNTER (NFREE).
B. CLEAR THE PART OF THE PARTICLE ARRAY PREVIOUSLY OCCUPIED BY THE BLOCK OF PARTICLES JUST DUMPED.
FINISHED DUMPING?
NO
YES
SEE THAT ENOUGH CONTIGUOUS BLANK LINES ARE IN THE TOP OF THE PARTICLE ARRAY TO RECEIVE THE INCOMING N PARTICLE DESCRIPTIONS
RETURN

FC-2. Organizational Flow Chart for Subroutine DUMPP


START
MUST ANY PARTICLE DESCRIPTIONS BE DUMPED?
N > NFREE
NO
JTEST = 0
GO TO 152
YES
151
WOULD DUMPING THE GROUNDED PARTICLES MAKE SUFFICIENT ROOM FOR THE BLOCK OF N INCOMING PARTICLES?
(NFREE + NG) ≥ N
YES
PREPARE TO DUMP GROUNDED PARTICLE DESCRIPTIONS
JTEST 1 = 1 JTEST = NG
NO
FIND THE IDENTITY (JTEST 1) AND SIZE (JTEST) OF THE LARGEST CLASS
18
IS SIZE OF SELECTED CLASS ≤ 0?
JTEST ≤ 0?
YES
IRROR = 184
7734
CALL ERROR
RETURN
NO
IS SIZE OF SELECTED CLASS > NBMAX?
JTEST > NBMAX
YES
JTEST = NBMAX
NO
GO TO 181

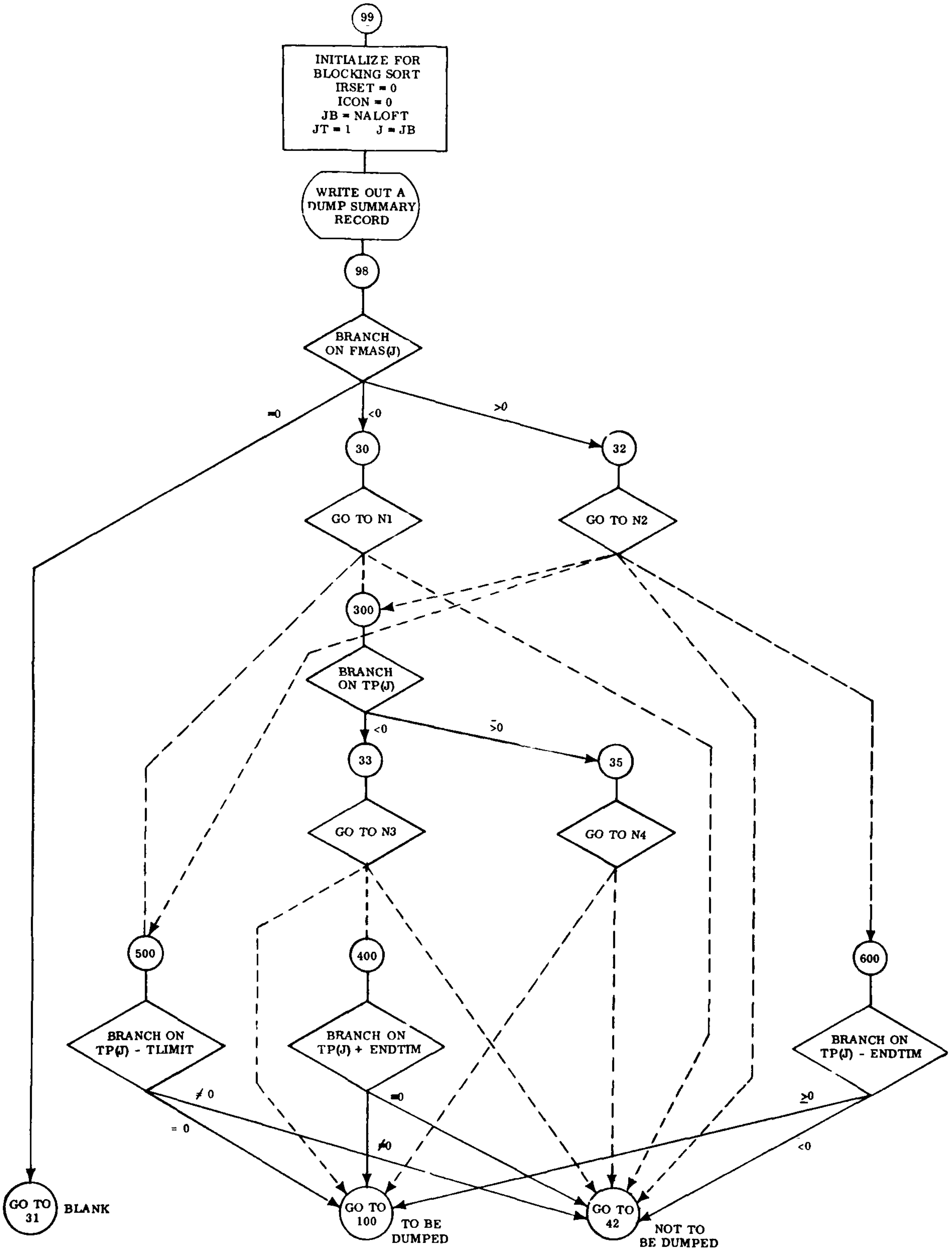
(a)

FC-3. Detailed Flow Charts for Subroutine DUMPP



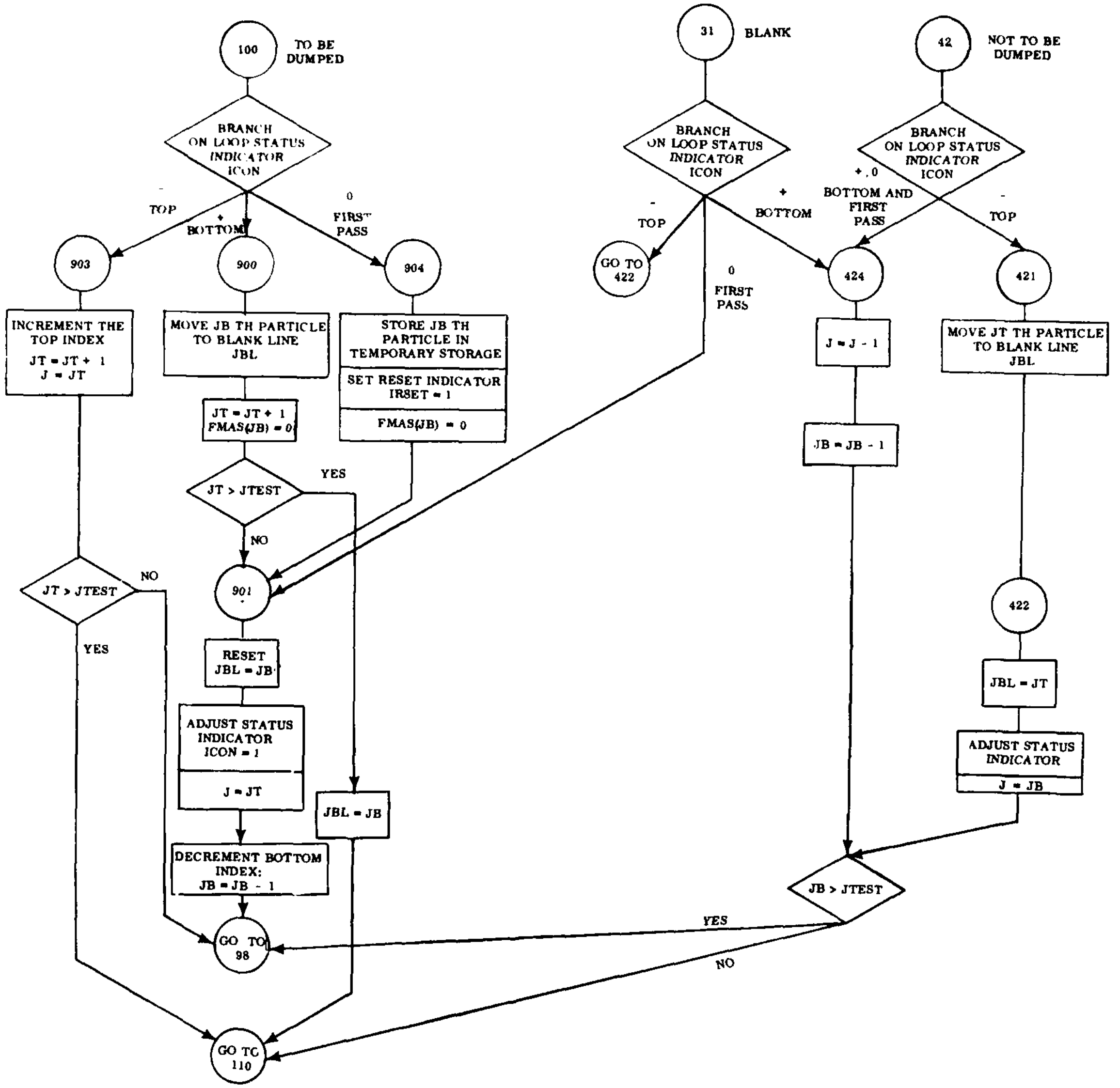
(b)

FC-3. (Continued) Detailed Flow Charts for Subroutine DUMPP



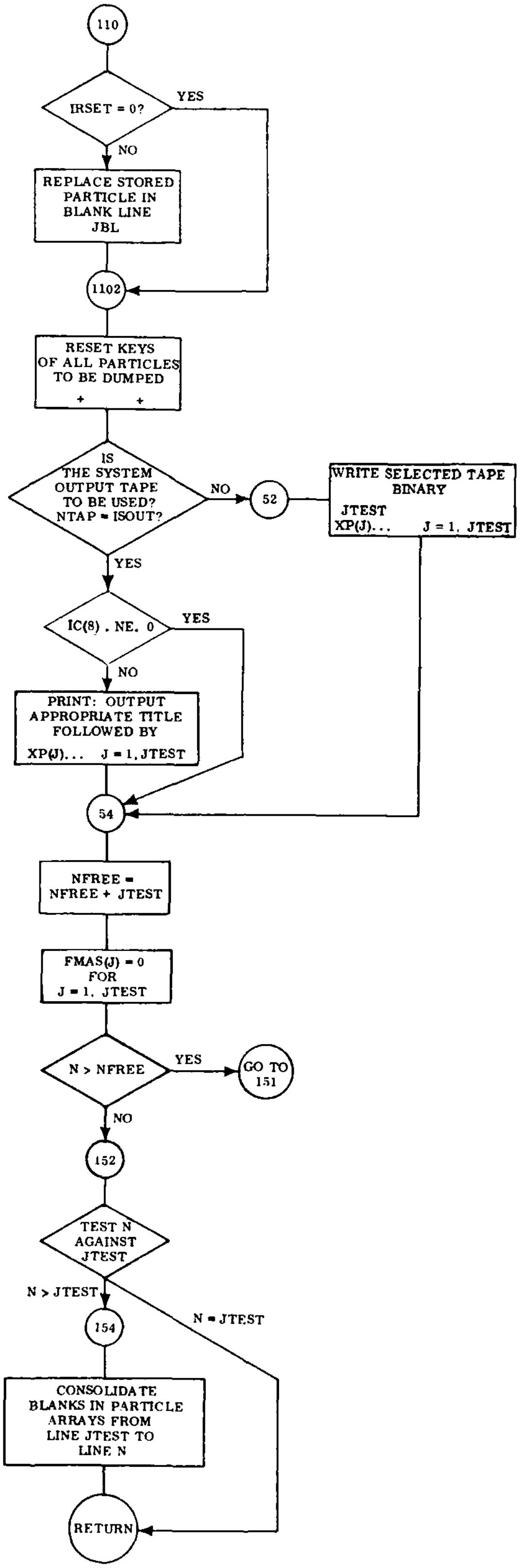
(c)

FC-3. (Continued) Detailed Flow Charts for Subroutine DUMPP



(d)

FC-3. (Continued) Detailed Flow Chart for Subroutine DUMPP


110
IRSET = 0?
YES
NO
REPLACE STORED PARTICLE IN BLANK LINE JBL
1102
RESET KEYS OF ALL PARTICLES TO BE DUMPED
+ +
IS THE SYSTEM OUTPUT TAPE TO BE USED? NTAP = ISOUT?
NO
52
WRITE SELECTED TAPE BINARY
JTEST
XP(J)... J = 1, JTEST
YES
IC(8) . NE. 0
YES
NO
PRINT: OUTPUT APPROPRIATE TITLE FOLLOWED BY
XP(J)... J = 1, JTEST
54
NFREE = NFREE + JTEST
FMAS(J) = 0 FOR J = 1, JTEST
N > NFREE
YES
GO TO 151
NO
152
TEST N AGAINST JTEST
N > JTEST
N = JTEST
154
CONSOLIDATE BLANKS IN PARTICLE ARRAYS FROM LINE JTEST TO LINE N
RETURN

(e)

FC-3. (Continued) Detailed Flow Chart for Subroutine DUMPP

Subroutine RDTOPO (no flow chart)

This subroutine is used by both LINK5 and LINK7 to read topographic data from the topographic data tape IHTOPO. The contents of tape IHTOPO are described in detail in the User Information section, and the FORTRAN variables referred to below are defined there.

For each block of topography data to be read, subroutine RDTOPO checks the values of II, JJ, and KK to determine whether they are within the prescribed range of values to avoid the possibility of an overflow in core storage beyond the space reserved for the arrays. If an error is found, the comment — INCORRECT TOPO TABLE OF CONTENTS — is made and execution of the run is terminated. If satisfactory values of II, JJ, and KK are found, the arrays S and SUBSID are read into core memory from tape IHTOPO, and control is returned to the calling program.

Subroutine LINK5 (FC-4 and FC-5)

This program acts as an initializer and controller for the Transport Module. Upon the first entrance to LINK5 it initializes parameters and reads the following information from the IBSYS input tape: a transport identifier, transport control data (array IC(J)), and the transport time limit (TLIMIT). Based on the control data LINK5 next rewinds only those tapes that may be used during transport. If a piecewise-planar topography tape is to be used, its identifier is next read and checked. If the wrong tape has been mounted, a comment is written and the program awaits operator action before trying again. Next, the tape of particles, IPARIN,* ready for transport is checked in a manner similar to that used on the topography tape. When found to be correct the program next reads from this tape (IPARIN) a number of data sets that are needed by either transport or the output processor, or both. Included in these data sets are: detonation parameters; the Cloud Rise-Transport Interface Module run identifier;the cloud-rise identifier; the detonation identifier; the fallout particle density; tabulated distributions of particle mass, activity (optional), and surface-to-volume ratio as functions of particle diameter; and a tabulated atmospheric description that consists of viscosity and density versus altitude.

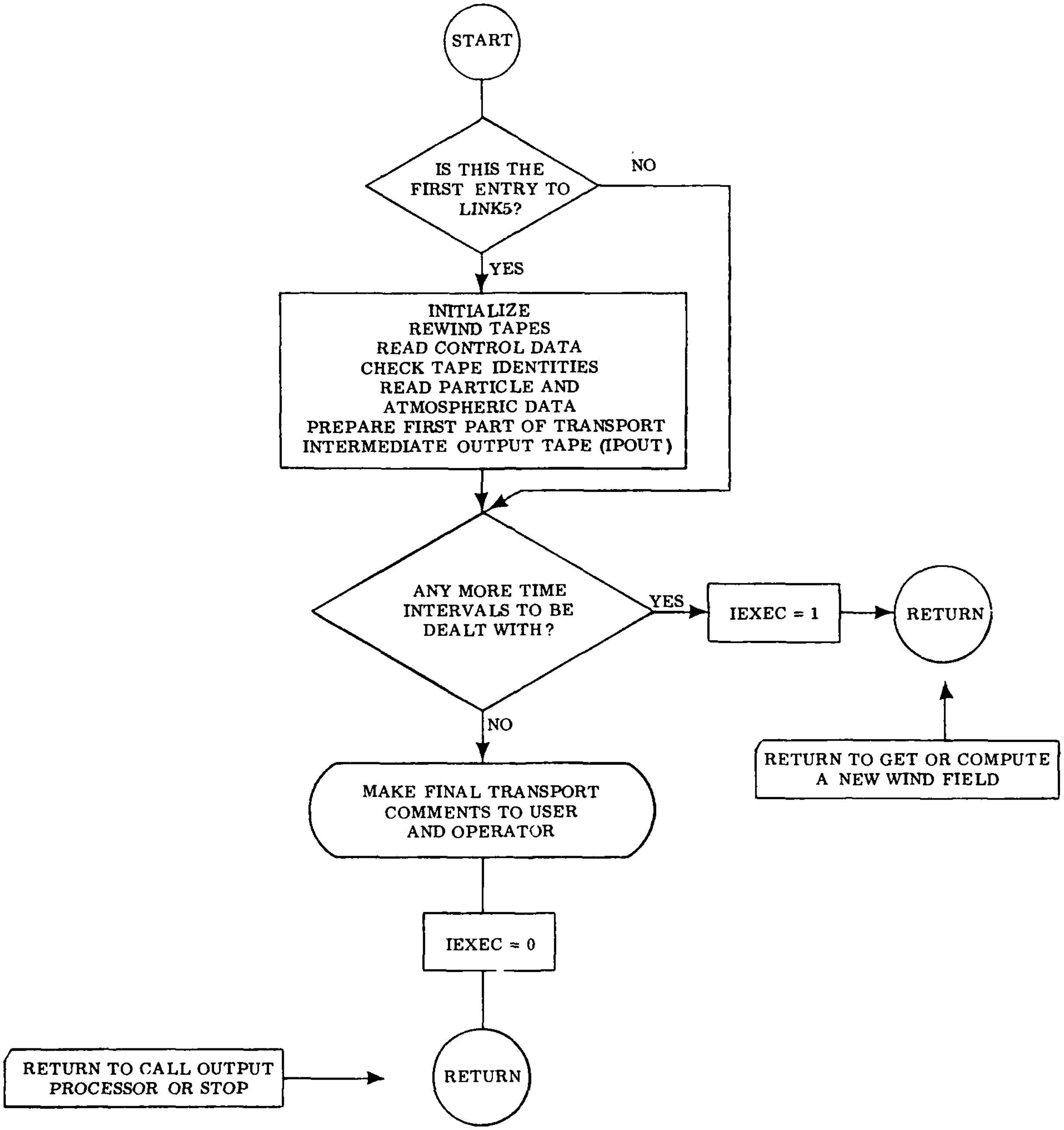
*Tape IPARIN has been prepared by the Cloud Rise-Transport Interface Module. See DASA-1800-III.

Next, a parameter (FROG) is computed that is required by the particle setting rate computations (subroutine FALRAT). Then if a piecewise-planar topography tape is not to be used, a height is read and stored for use as the height of a fully planar topography and a transfer is made to statement 205 where wind data are read. On the other hand, if a piecewise-planar topography is to be used, its identifier and table of contents are read from the tape IHTOPO. The parameter HTOPO is set at the highest topographic height on the whole tape and the first topo data block is read by calling subroutine RDTOPO.

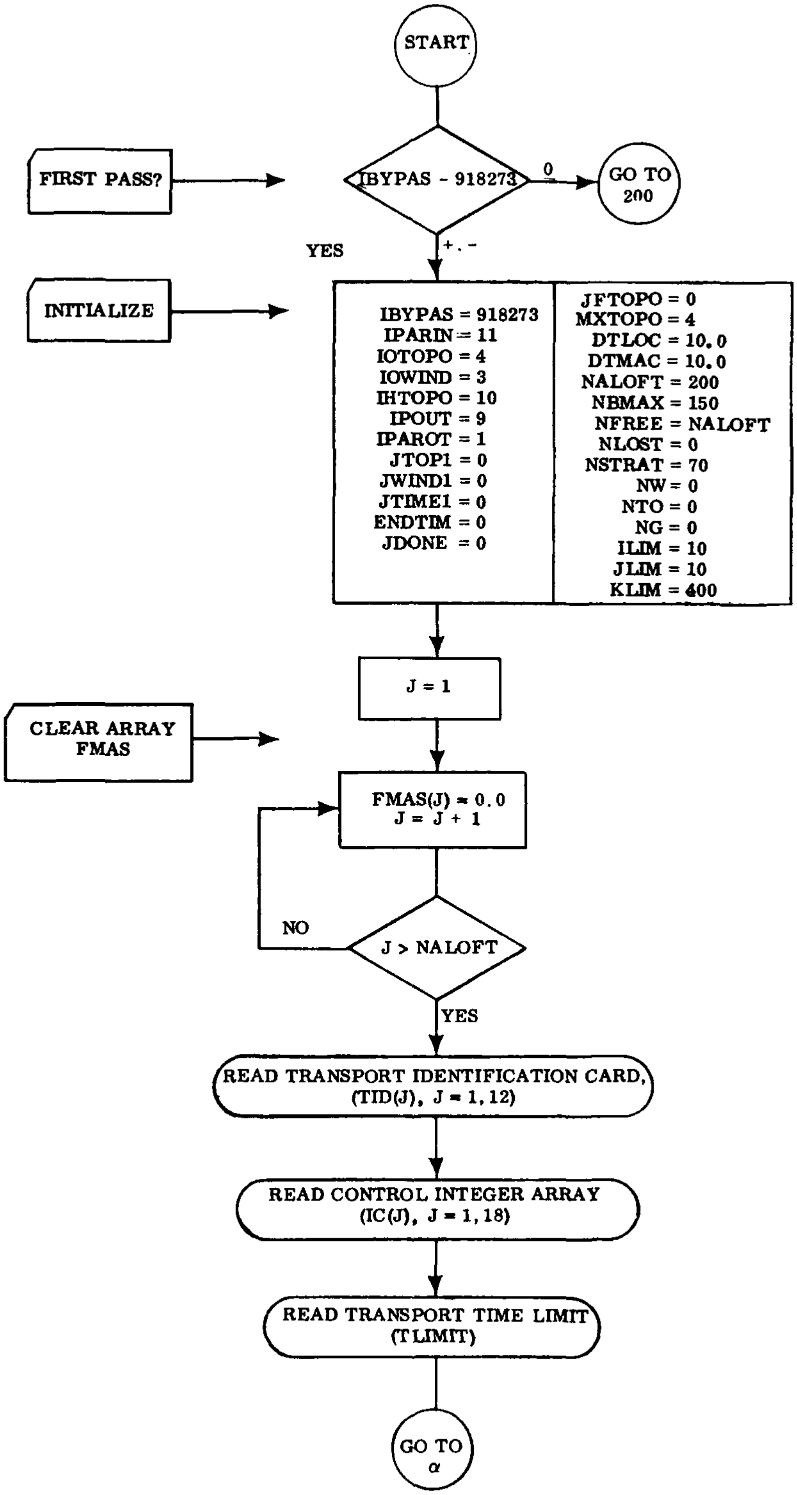
At 205 the program reads a wind-field data set identifier from the system input tape and transfers to the transport output tape (IPOUT) all identifiers and descriptive tables required by the output processor. Next LINK5 prints a title page for the transport run including identifiers and atmospheric data and then transfers to 200 where the transport executive begins.

Statement 200 is the place to which control is immediately transferred upon any entrance to LINK5 except for the first. At 200 TLIMIT and ENDTIM are compared to determine if the processing of the Transport Module has been completed. Note that transport is considered to be unfinished so long as ENDTIM, the time at which the current wind field must be updated is not greater (later) than the user-specified time of transport cutoff (TLIMIT). (ENDTIM is initialized to 0.0 on the first pass through LINK5. It is assigned its true value by the wind description program MKWIND which is called by LINK6, subsequent to LINK5, when LINK5 has set IEXEC = 1 at statement number 400.)

When transport has been completed, LINK5 sets N = NALOFT and calls DUMPP to dispose of any particle descriptions that may remain within core memory. Next, if any particles remain on the time boundary tape they are read in and printed as lost particles for the benefit of the user. Finally at 501 the terminating zero is written on the transport output tape (IPOUT), the comment — TRANSPORT IS COMPLETED, etc. — is written and the executive control word IEXEC is set to zero to cause a transfer to LINK8 of the Output Processor Module (see DASA-1800-VI.)

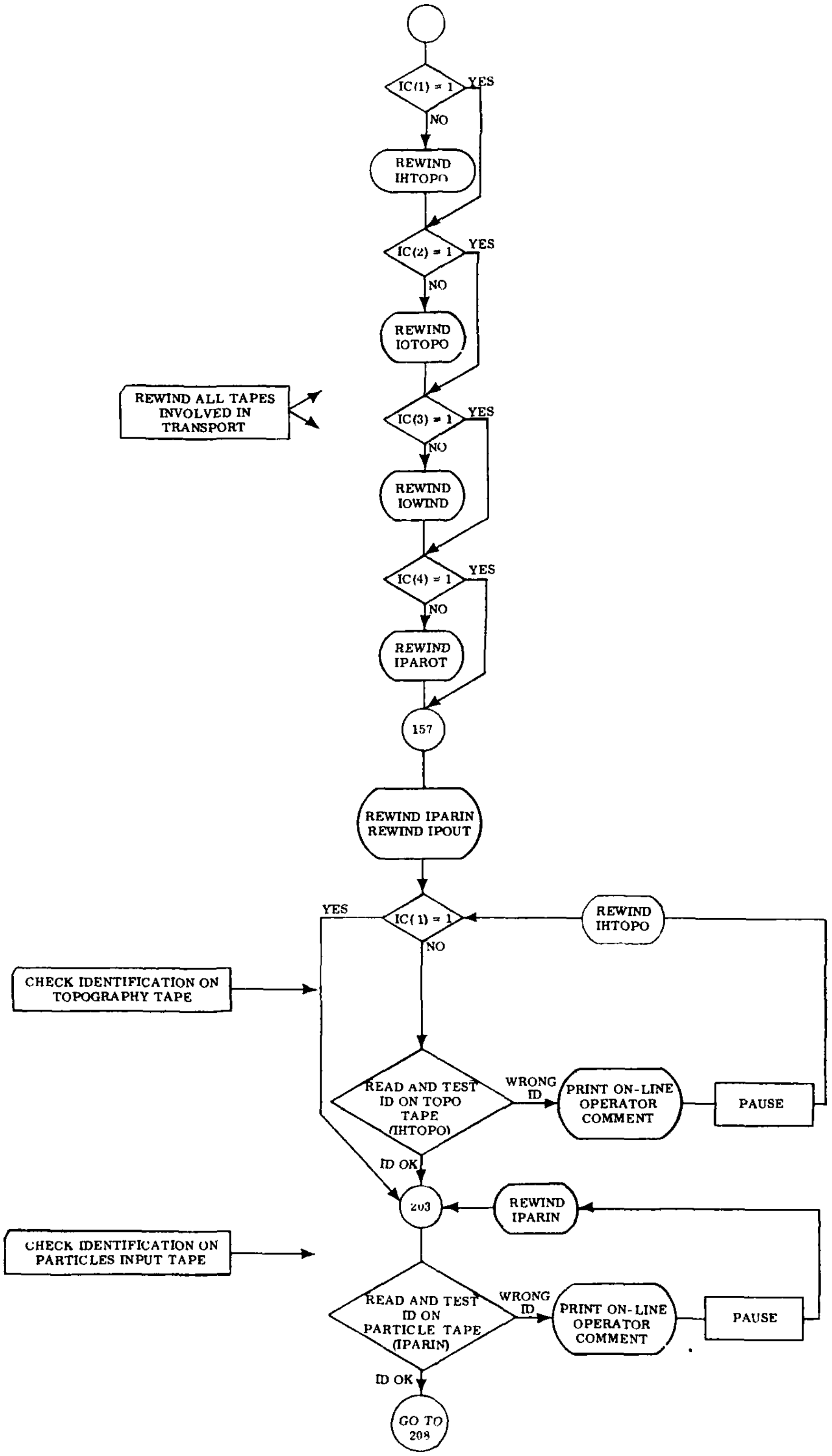

START
IS THIS THE FIRST ENTRY TO LINK5?
NO
YES
INITIALIZE
REWIND TAPES
READ CONTROL DATA
CHECK TAPE IDENTITIES
READ PARTICLE AND ATMOSPHERIC DATA
PREPARE FIRST PART OF TRANSPORT INTERMEDIATE OUTPUT TAPE (IPOUT)
ANY MORE TIME INTERVALS TO BE DEALT WITH?
YES
IEXEC = 1
RETURN
RETURN TO GET OR COMPUTE A NEW WIND FIELD
NO
MAKE FINAL TRANSPORT COMMENTS TO USER AND OPERATOR
IEXEC = 0
RETURN TO CALL OUTPUT PROCESSOR OR STOP
RETURN

FC-4. General Flow Chart for Subroutine LINK5



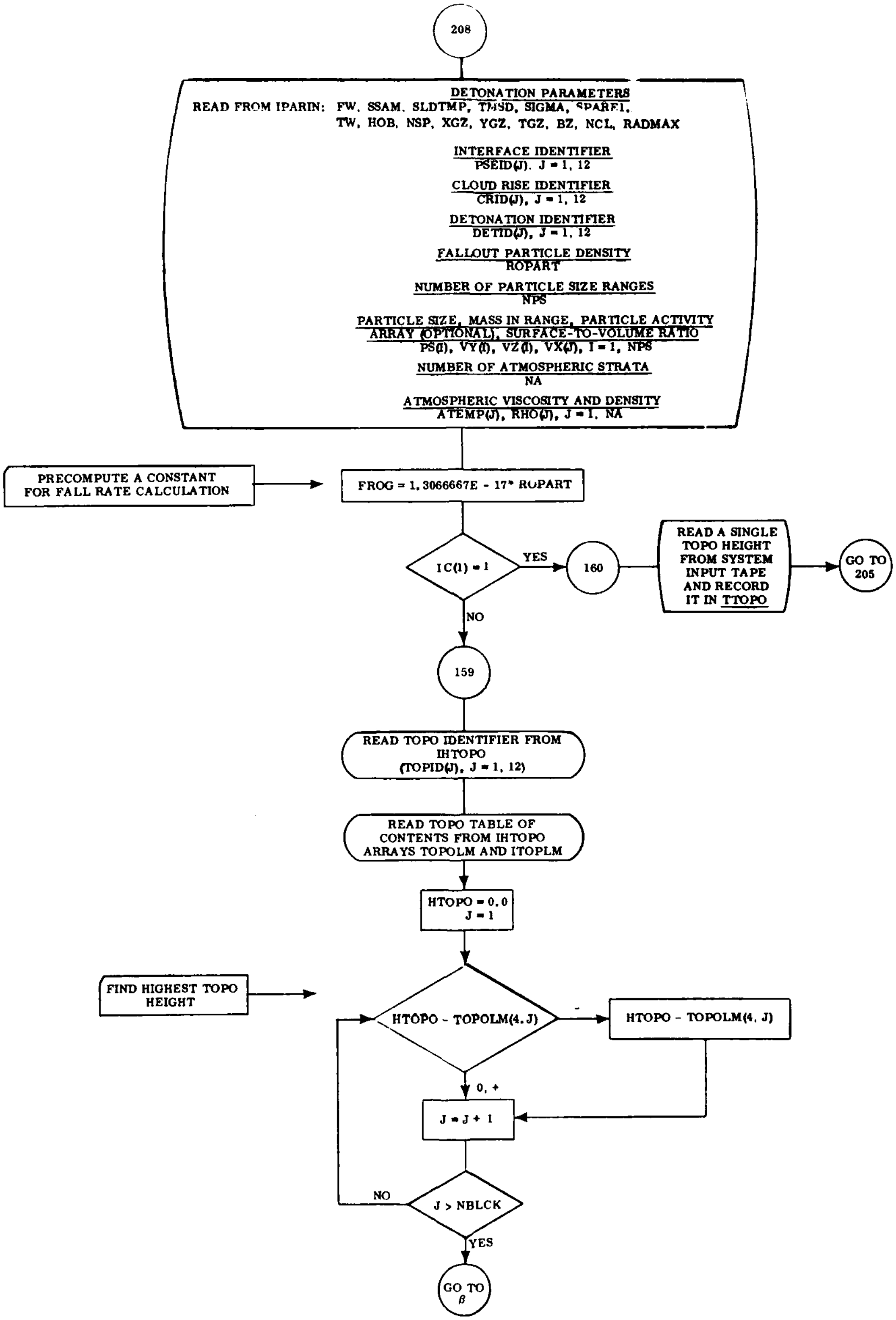
(a)

FC-5. Detailed Flow Charts for Subroutine LINK5


IC(1) = 1
YES
NO
REWIND IHTOPO
IC(2) = 1
YES
NO
REWIND IOTOPO
REWIND ALL TAPES INVOLVED IN TRANSPORT
IC(3) = 1
YES
NO
REWIND IOWIND
IC(4) = 1
YES
NO
REWIND IPAROT
157
REWIND IPARIN REWIND IPOUT
YES
IC(1) = 1
NO
REWIND IHTOPO
CHECK IDENTIFICATION ON TOPOGRAPHY TAPE
READ AND TEST ID ON TOPO TAPE (IHTOPO)
WRONG ID
PRINT ON-LINE OPERATOR COMMENT
PAUSE
ID OK
203
REWIND IPARIN
CHECK IDENTIFICATION ON PARTICLES INPUT TAPE
READ AND TEST ID ON PARTICLE TAPE (IPARIN)
WRONG ID
PRINT ON-LINE OPERATOR COMMENT
PAUSE
ID OK
GO TO 208

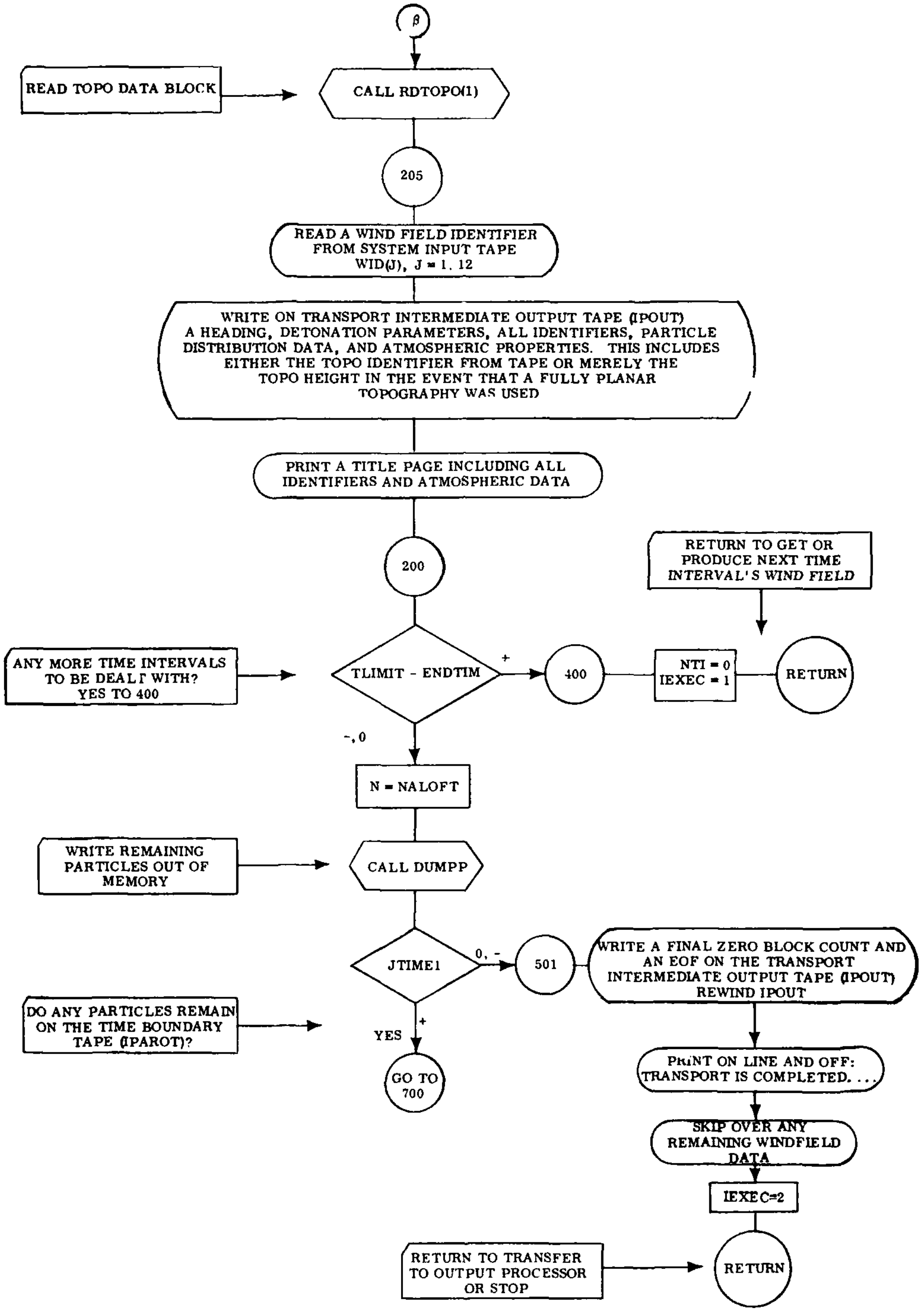
(b)

FC-5. (Continued) Detailed Flow Charts for Subroutine LINK5


208
DETONATION PARAMETERS
READ FROM IPARIN: FW, SSAM, SLDTMP, TMSD, SIGMA, SPARE1,
TW, HOB, NSP, XGZ, YGZ, TGZ, BZ, NCL, RADMAX
INTERFACE IDENTIFIER
PSEID(J), J = 1, 12
CLOUD RISE IDENTIFIER
CRID(J), J = 1, 12
DETONATION IDENTIFIER
DETID(J), J = 1, 12
FALLOUT PARTICLE DENSITY
ROPART
NUMBER OF PARTICLE SIZE RANGES
NPS
PARTICLE SIZE, MASS IN RANGE, PARTICLE ACTIVITY
ARRAY (OPTIONAL), SURFACE-TO-VOLUME RATIO
PS(I), VY(I), VZ(I), VX(J), I = 1, NPS
NUMBER OF ATMOSPHERIC STRATA
NA
ATMOSPHERIC VISCOSITY AND DENSITY
ATEMP(J), RHO(J), J = 1, NA
PRECOMPUTE A CONSTANT FOR FALL RATE CALCULATION
FROG = 1.3066667E - 17* ROPART
IC(1) = 1
YES
160
READ A SINGLE TOPO HEIGHT FROM SYSTEM INPUT TAPE AND RECORD IT IN TTOPO
GO TO 205
NO
159
READ TOPO IDENTIFIER FROM IHTOPO (TOPID(J), J = 1, 12)
READ TOPO TABLE OF CONTENTS FROM IHTOPO ARRAYS TOPOLM AND ITOPLM
HTOPO = 0.0
J = 1
FIND HIGHEST TOPO HEIGHT
HTOPO - TOPOLM(4, J)
-
HTOPO - TOPOLM(4, J)
0, +
J = J + 1
NO
J > NBLCK
YES
GO TO β

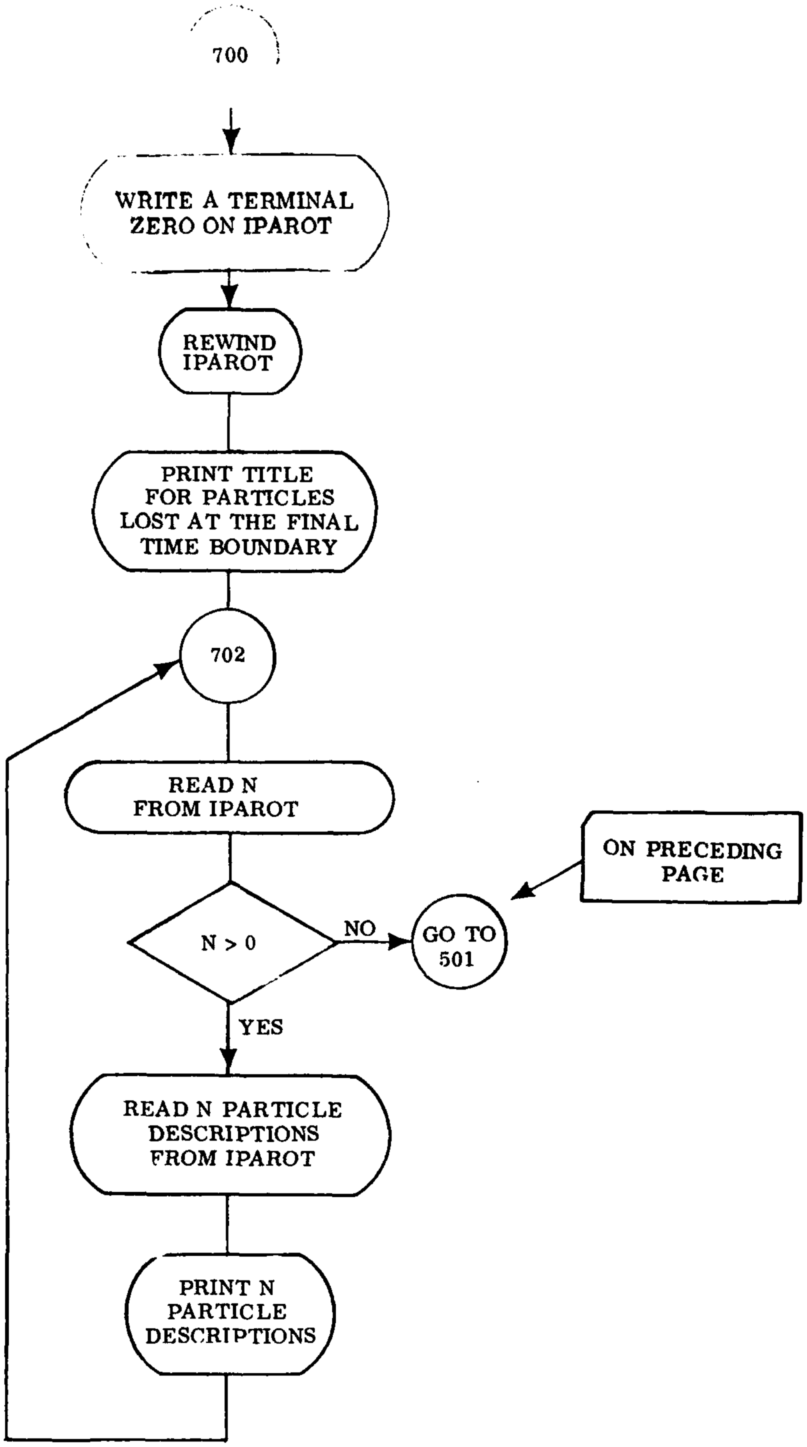
(c)

FC-5. (Continued) Detailed Flow Charts for Subroutine LINK5


β
READ TOPO DATA BLOCK
CALL RDTOPO(1)
205
READ A WIND FIELD IDENTIFIER FROM SYSTEM INPUT TAPE WID(J), J = 1, 12
WRITE ON TRANSPORT INTERMEDIATE OUTPUT TAPE (IPOUT) A HEADING, DETONATION PARAMETERS, ALL IDENTIFIERS, PARTICLE DISTRIBUTION DATA, AND ATMOSPHERIC PROPERTIES. THIS INCLUDES EITHER THE TOPO IDENTIFIER FROM TAPE OR MERELY THE TOPO HEIGHT IN THE EVENT THAT A FULLY PLANAR TOPOGRAPHY WAS USED
PRINT A TITLE PAGE INCLUDING ALL IDENTIFIERS AND ATMOSPHERIC DATA
200
RETURN TO GET OR PRODUCE NEXT TIME INTERVAL'S WIND FIELD
ANY MORE TIME INTERVALS TO BE DEALT WITH? YES TO 400
TLIMIT - ENDTIM
+
400
NTI = 0
IEXEC = 1
RETURN
-, 0
N = NALOFT
WRITE REMAINING PARTICLES OUT OF MEMORY
CALL DUMPP
JTIME1
0, -
501
WRITE A FINAL ZERO BLOCK COUNT AND AN EOF ON THE TRANSPORT INTERMEDIATE OUTPUT TAPE (IPOUT) REWIND IPOUT
DO ANY PARTICLES REMAIN ON THE TIME BOUNDARY TAPE (IPAROT)?
+
YES
GO TO 700
PRINT ON LINE AND OFF: TRANSPORT IS COMPLETED. . . .
SKIP OVER ANY REMAINING WINDFIELD DATA
IEXEC=2
RETURN TO TRANSFER TO OUTPUT PROCESSOR OR STOP
RETURN

(d)

FC-5. (Continued) Detailed Flow Charts for Subroutine LINK5


700
WRITE A TERMINAL ZERO ON IPAROT
REWIND IPAROT
PRINT TITLE FOR PARTICLES LOST AT THE FINAL TIME BOUNDARY
702
READ N FROM IPAROT
N > 0
NO
GO TO 501
ON PRECEDING PAGE
YES
READ N PARTICLE DESCRIPTIONS FROM IPAROT
PRINT N PARTICLE DESCRIPTIONS

(e)

FC-5. (Continued) Detailed Flow Charts for Subroutine LINK5

Subroutine LINK6 (no flow chart)

This program merely calls subroutine MKWIND, the wind-field description subroutine. It has been left as a separate subroutine in anticipation of its use as a branch point to select the desired program to be used for the wind-field description.

Subroutine RDCIRS (FC-6)

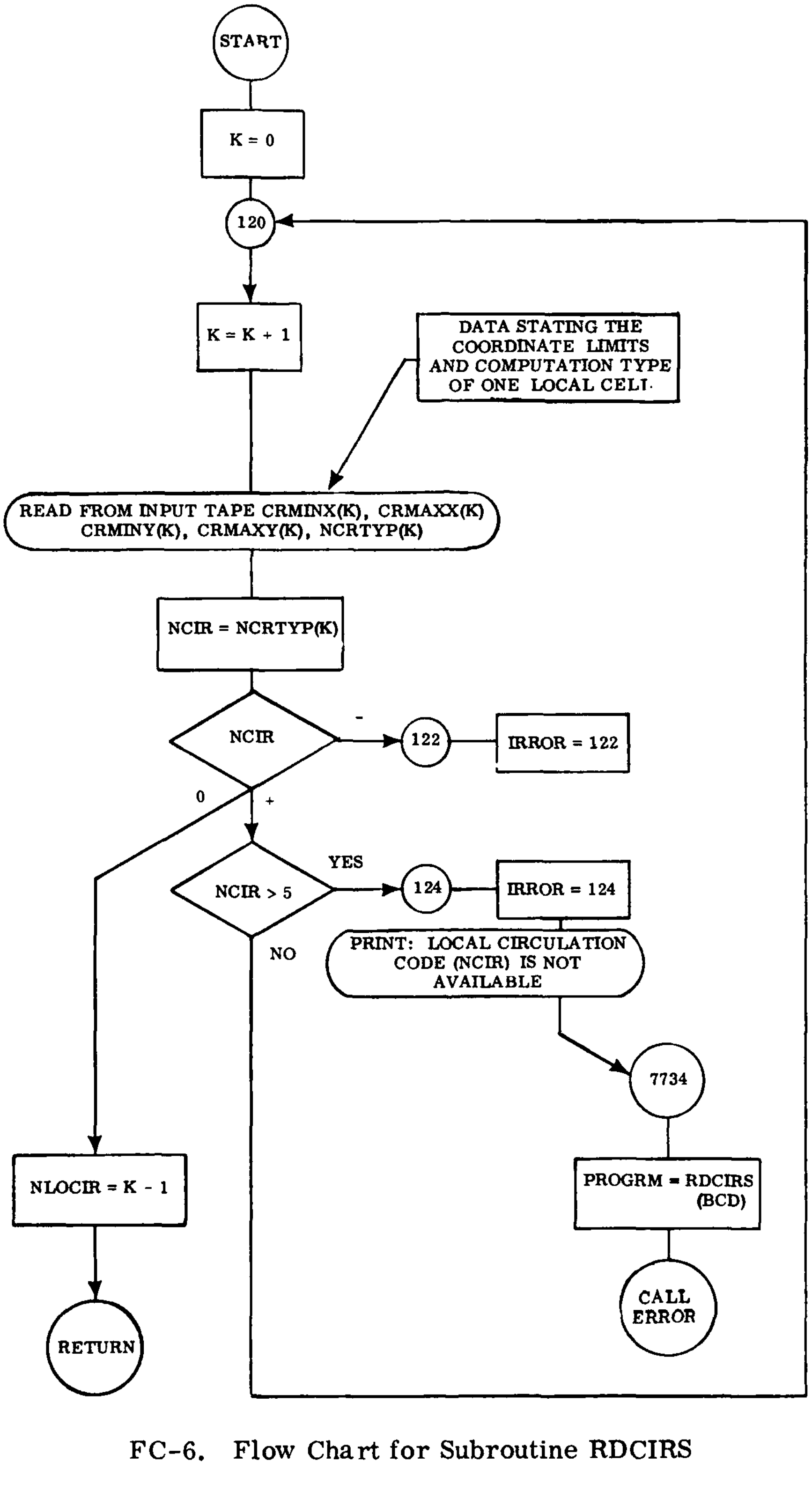
The purpose of this subroutine is to read a set of data which describes the geographical limits of the area covered by each of the local circulation systems that are to be used within the transport. Also, the identification number (NCRTYP(K)) for the computation code (local circulation model) applicable within each of the local circulation cells is read. At the time of this writing only three types of local circulation systems are used:

Identification Number	Program to be Used	Model
1	MTWND1	Mountain wind
2	RGWND1	Ridge wind
3	CBREZ1	Sea breeze

The data are read from the IBSYS input tape, one card image at a time, with all data pertaining to the Kth local circulation area appearing on the same card. A count of card images read is accumulated in variable K and reading is terminated whenever a blank card (NCRTYP(K) = 0) is encountered. At this time the number of local cells for which data have been read is stored in NLOCIR and a return is made to the calling program. An error stop occurs whenever a circulation code identifier (NCRTYP(K)) which is either negative or greater than 5 is encountered.

Subroutine MKWIND (FC-7 and FC-8)

This subroutine forms and stores in core a horizontally and vertically variant wind description on the basis of inputs from the IBSYS input tape. Inputs are as follows:


START
K = 0
120
K = K + 1
DATA STATING THE COORDINATE LIMITS AND COMPUTATION TYPE OF ONE LOCAL CELL
READ FROM INPUT TAPE CRMINX(K), CRMAXX(K) CRMINY(K), CRMAXY(K), NCRTYP(K)
NCIR = NCRTYP(K)
NCIR
-
122
IRROR = 122
0
+
NCIR > 5
YES
124
IRROR = 124
NO
PRINT: LOCAL CIRCULATION CODE (NCIR) IS NOT AVAILABLE
7734
PROGRM = RDCIRS (BCD)
CALL ERROR
NLOCIR = K - 1
RETURN

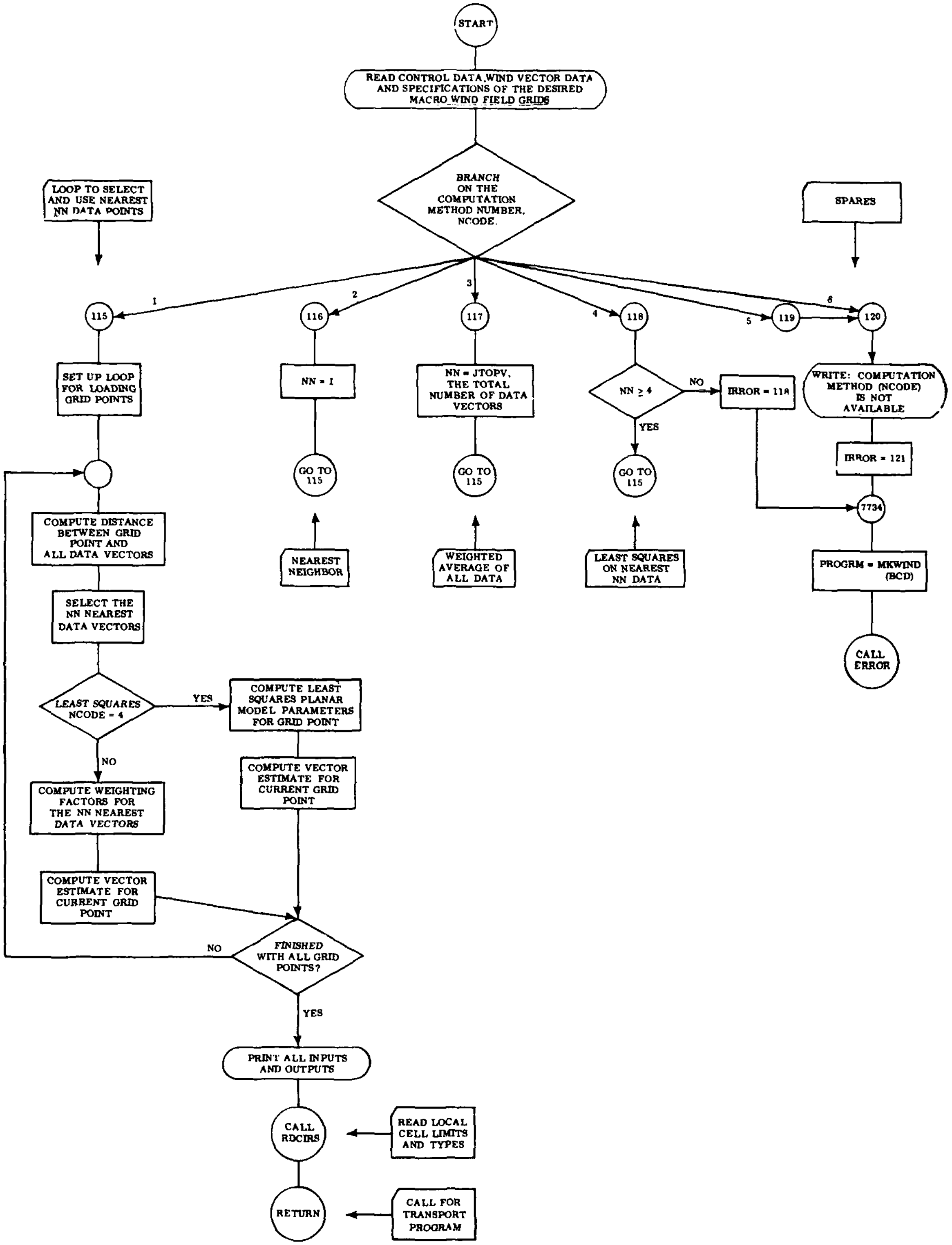
FC-6. Flow Chart for Subroutine RDCIRS

1. Control variables ENDTIM, which gives the time at which wind field to be constructed from the following data ceases to be valid; ALPHA and BETA, which are weighting parameters to be applied to vertical and horizontal distances (see Eq (21) ff.); NN, which specifies the number of nearest vectors to be used in estimating the wind vector at a grid point; and NCODE, which identifies the desired computational option.

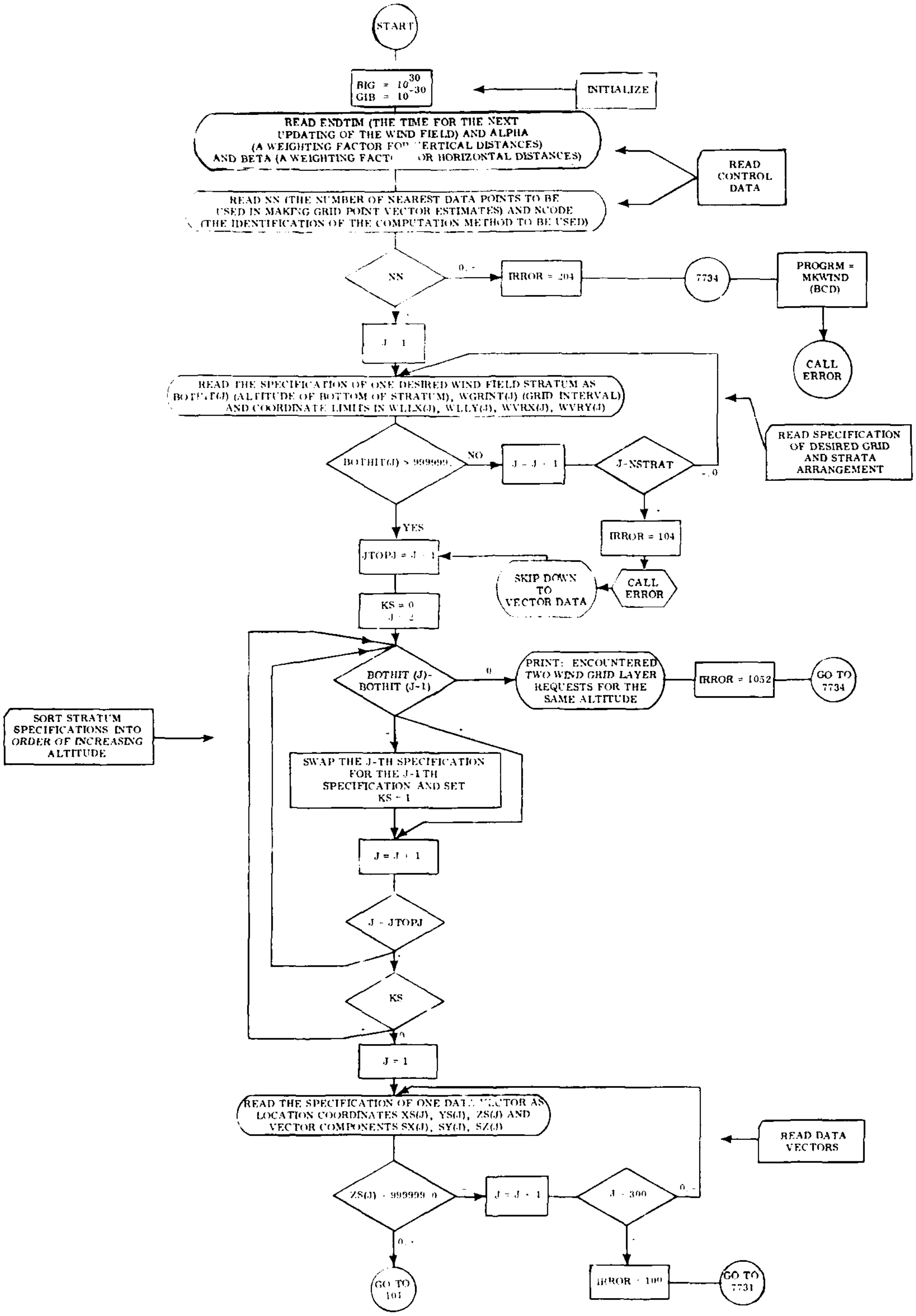
2. Specifications for constructing the wind-field grid for the Jth vertical stratum in the form BOTHIT(J), WGRINT(J), WLLX(J), WLLY(J), WURX(J), and WURY(J); BOTHIT(J) is the height of the bottom of the Jth stratum, WGRINT(J) is the grid interval to be used in the Jth stratum, and WLLX(J), WLLY(J), WURX(J), WURY(J) are lower left corner and upper right corner limit coordinates. Note that each stratum specification is independent of all others. The specification input is terminated when a value BOTHIT(J) $\geq$ 999999.0 is encountered.

3. Wind vector data from which the wind field is to be constructed: ZS(K), XS(K), YS(K), SX(K), SY(K), and SZ(K); ZS(K) is the height of the Kth vector, XS is the east-west coordinate of the Kth vector, YS is the north-south coordinate of the Kth vector, SX(K) is the eastward component of the Kth vector, SY(K) is the northward component of the Kth vector, and SZ(K) is the upward component of the Kth vector. The vector reading operation is terminated when a value ZS(K) $\geq$ 999999.0 is encountered.

A wind-field tape IS NOT WRITTEN by this program. Flow chart FC-7 is a functional flow chart of this program that shows how the four available computation options are arranged to use much of the same code. Flow chart FC-8 presents the details of the subroutine and may be used to follow the ensuing discussion.

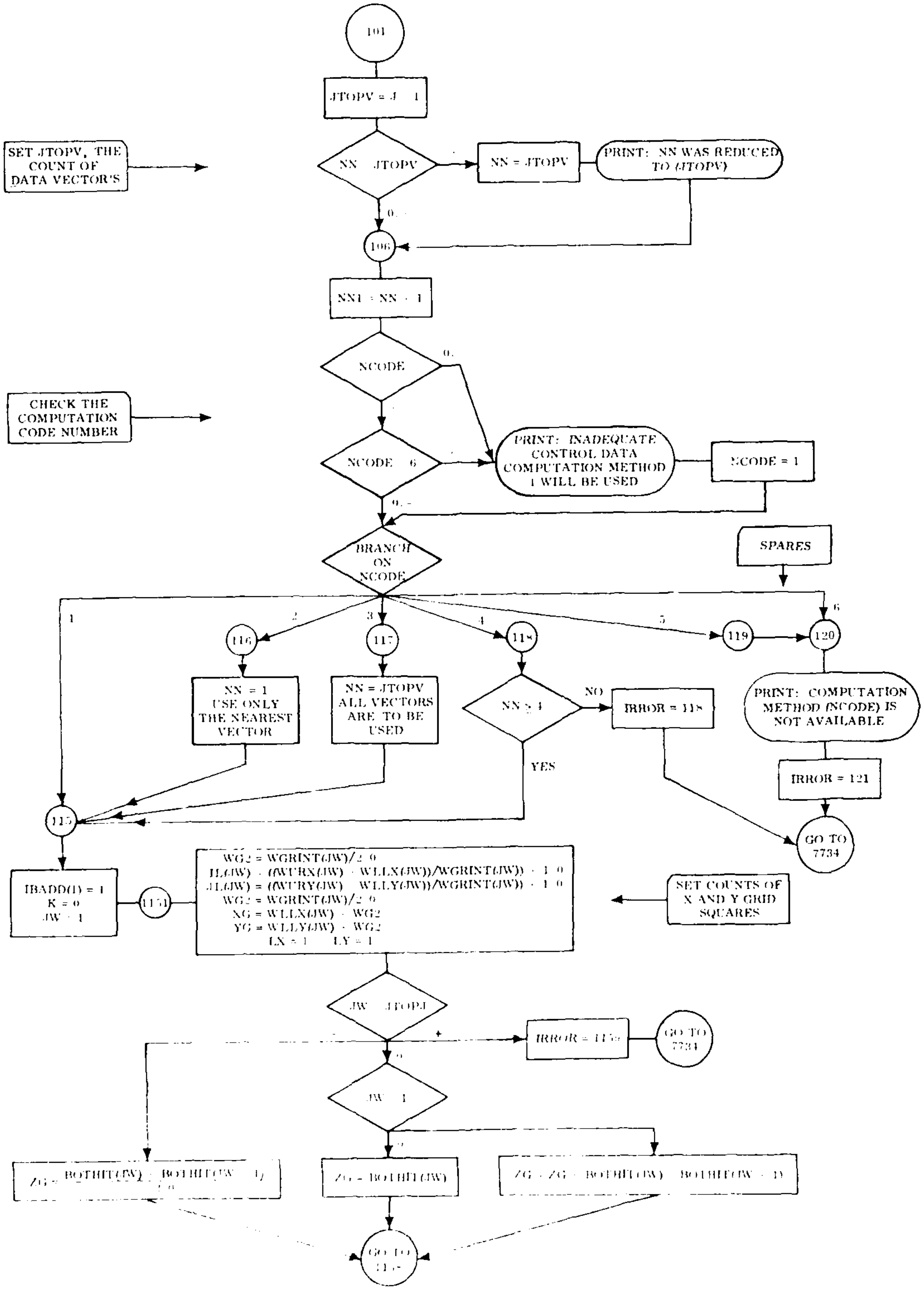

START
READ CONTROL DATA,WIND VECTOR DATA AND SPECIFICATIONS OF THE DESIRED MACRO WIND FIELD GRIDS
BRANCH ON THE COMPUTATION METHOD NUMBER, NCODE.
LOOP TO SELECT AND USE NEAREST NN DATA POINTS
SPARES
1
2
3
4
5
6
115
116
117
118
119
120
SET UP LOOP FOR LOADING GRID POINTS
NN = 1
NN = JTOPV, THE TOTAL NUMBER OF DATA VECTORS
NN ≥ 4
NO
YES
IRROR = 118
WRITE: COMPUTATION METHOD (NCODE) IS NOT AVAILABLE
IRROR = 121
GO TO 115
GO TO 115
GO TO 115
7734
NEAREST NEIGHBOR
WEIGHTED AVERAGE OF ALL DATA
LEAST SQUARES ON NEAREST NN DATA
PROGRM = MKWIND (BCD)
CALL ERROR
COMPUTE DISTANCE BETWEEN GRID POINT AND ALL DATA VECTORS
SELECT THE NN NEAREST DATA VECTORS
LEAST SQUARES NCODE = 4
YES
COMPUTE LEAST SQUARES PLANAR MODEL PARAMETERS FOR GRID POINT
NO
COMPUTE WEIGHTING FACTORS FOR THE NN NEAREST DATA VECTORS
COMPUTE VECTOR ESTIMATE FOR CURRENT GRID POINT
COMPUTE VECTOR ESTIMATE FOR CURRENT GRID POINT
NO
FINISHED WITH ALL GRID POINTS?
YES
PRINT ALL INPUTS AND OUTPUTS
CALL RDCIRS
READ LOCAL CELL LIMITS AND TYPES
RETURN
CALL FOR TRANSPORT PROGRAM

FC-7. Organizational Flow Chart for Subroutine MKWIND


START
BIG = 10^30
GIB = 10^-30
INITIALIZE
READ ENDTIM (THE TIME FOR THE NEXT UPDATING OF THE WIND FIELD) AND ALPHA (A WEIGHTING FACTOR FO" 'ERTICAL DISTANCES) AND BETA (A WEIGHTING FACT OR HORIZONTAL DISTANCES)
READ CONTROL DATA
READ NN (THE NUMBER OF NEAREST DATA POINTS TO BE USED IN MAKING GRID POINT VECTOR ESTIMATES) AND NCODE (THE IDENTIFICATION OF THE COMPUTATION METHOD TO BE USED)
NN
0, -
IRROR = 204
7734
PROGRM = MKWIND (BCD)
CALL ERROR
J 1
READ THE SPECIFICATION OF ONE DESIRED WIND FIELD STRATUM AS BOTHIT(J) (ALTITUDE OF BOTTOM OF STRATUM), WGRINT(J) (GRID INTERVAL) AND COORDINATE LIMITS IN WLLX(J), WLLY(J), WVRX(J), WVRY(J)
READ SPECIFICATION OF DESIRED GRID AND STRATA ARRANGEMENT
BOTHIT(J) > 999999.
NO
J = J + 1
J-NSTRAT
-, 0
IRROR = 104
CALL ERROR
YES
JTOPJ = J - 1
SKIP DOWN TO VECTOR DATA
KS = 0
J = 2
BOTHIT (J)-BOTHIT (J-1)
0
PRINT: ENCOUNTERED TWO WIND GRID LAYER REQUESTS FOR THE SAME ALTITUDE
IRROR = 1052
GO TO 7734
SORT STRATUM SPECIFICATIONS INTO ORDER OF INCREASING ALTITUDE
SWAP THE J-TH SPECIFICATION FOR THE J-1TH SPECIFICATION AND SET KS = 1
J = J + 1
J - JTOPJ
KS
0
J = 1
READ THE SPECIFICATION OF ONE DATA VECTOR AS LOCATION COORDINATES XS(J), YS(J), ZS(J) AND VECTOR COMPONENTS SX(J), SY(J), SZ(J)
READ DATA VECTORS
ZS(J) - 999999. 0
J = J + 1
J - 300
0, -
0, +
GO TO 101
IRROR = 100
GO TO 7731

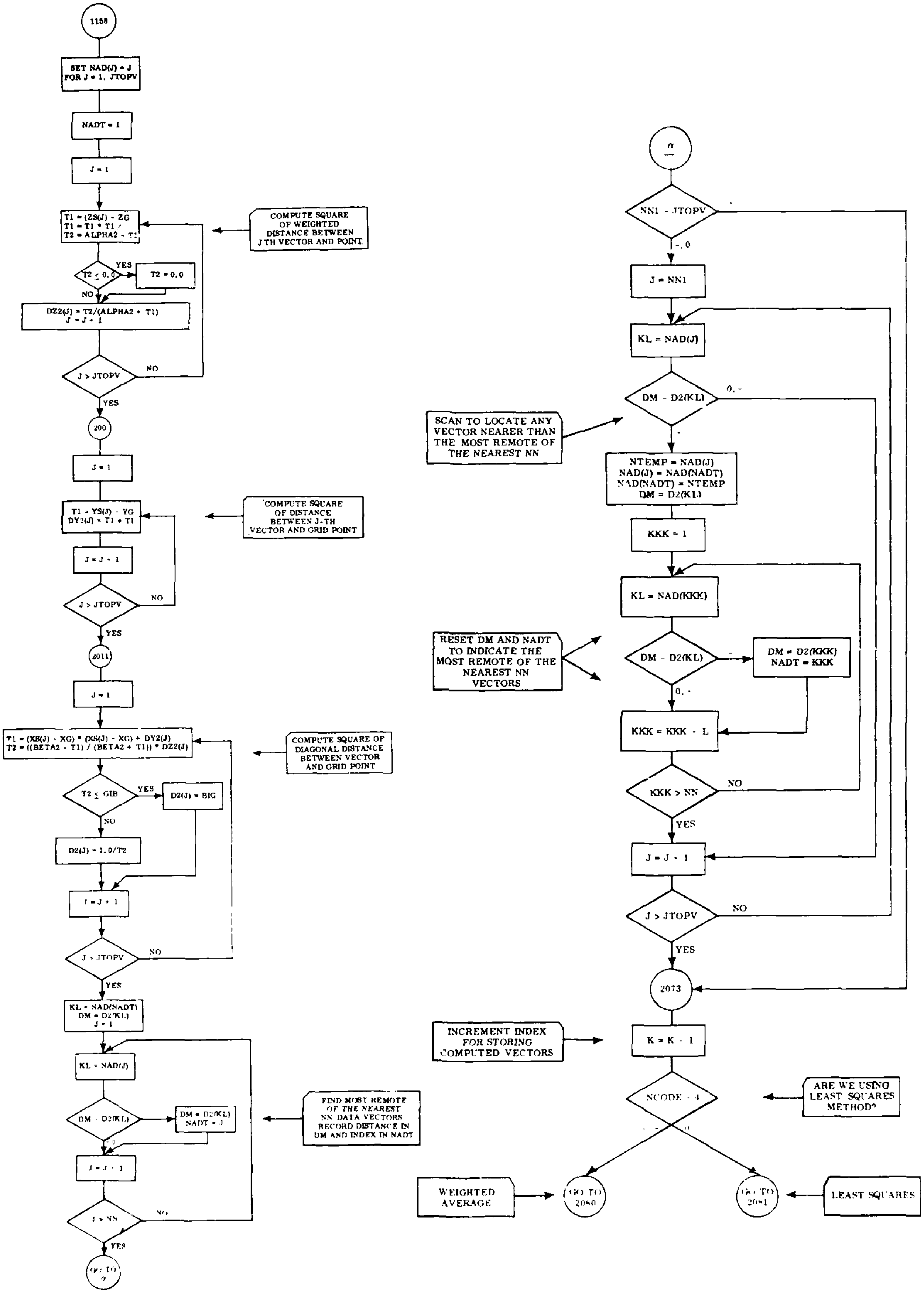
(a)

FC-8. Detailed Flow Charts for Subroutine MKWIND


101
JTOPV = J - 1
SET JTOPV, THE COUNT OF DATA VECTOR'S
NN JTOPV
NN = JTOPV
PRINT: NN WAS REDUCED TO (JTOPV)
0, -
106
NN1 = NN + 1
NCODE
0,
CHECK THE COMPUTATION CODE NUMBER
NCODE 6
PRINT: INADEQUATE CONTROL DATA COMPUTATION METHOD 1 WILL BE USED
NCODE = 1
0, -
BRANCH ON NCODE
SPARES
1
2
3
4
5
6
116
117
118
119
120
NN = 1 USE ONLY THE NEAREST VECTOR
NN = JTOPV ALL VECTORS ARE TO BE USED
NN ≥ 4
NO
YES
IRROR = 118
PRINT: COMPUTATION METHOD (NCODE) IS NOT AVAILABLE
IRROR = 121
GO TO 7734
115
IBADD(I) = 1
K = 0
JW = 1
1151
WG2 = WGRINT(JW)/2.0
IL(JW) = ((WURX(JW) - WLLX(JW))/WGRINT(JW)) + 1.0
JL(JW) = ((WURY(JW) - WLLY(JW))/WGRINT(JW)) + 1.0
WG2 = WGRINT(JW)/2.0
XG = WLLX(JW) + WG2
YG = WLLY(JW) + WG2
LX = 1 LY = 1
SET COUNTS OF X AND Y GRID SQUARES
JW JTOPJ
-
+
0
IRROR = 1150
GO TO 7734
JW 1
0
ZG = (BOTHIT(JW) + BOTHIT(JW - 1))/2.0
ZG = BOTHIT(JW)
ZG = ZG + BOTHIT(JW) - BOTHIT(JW - 1)
GO TO 115-

(b)

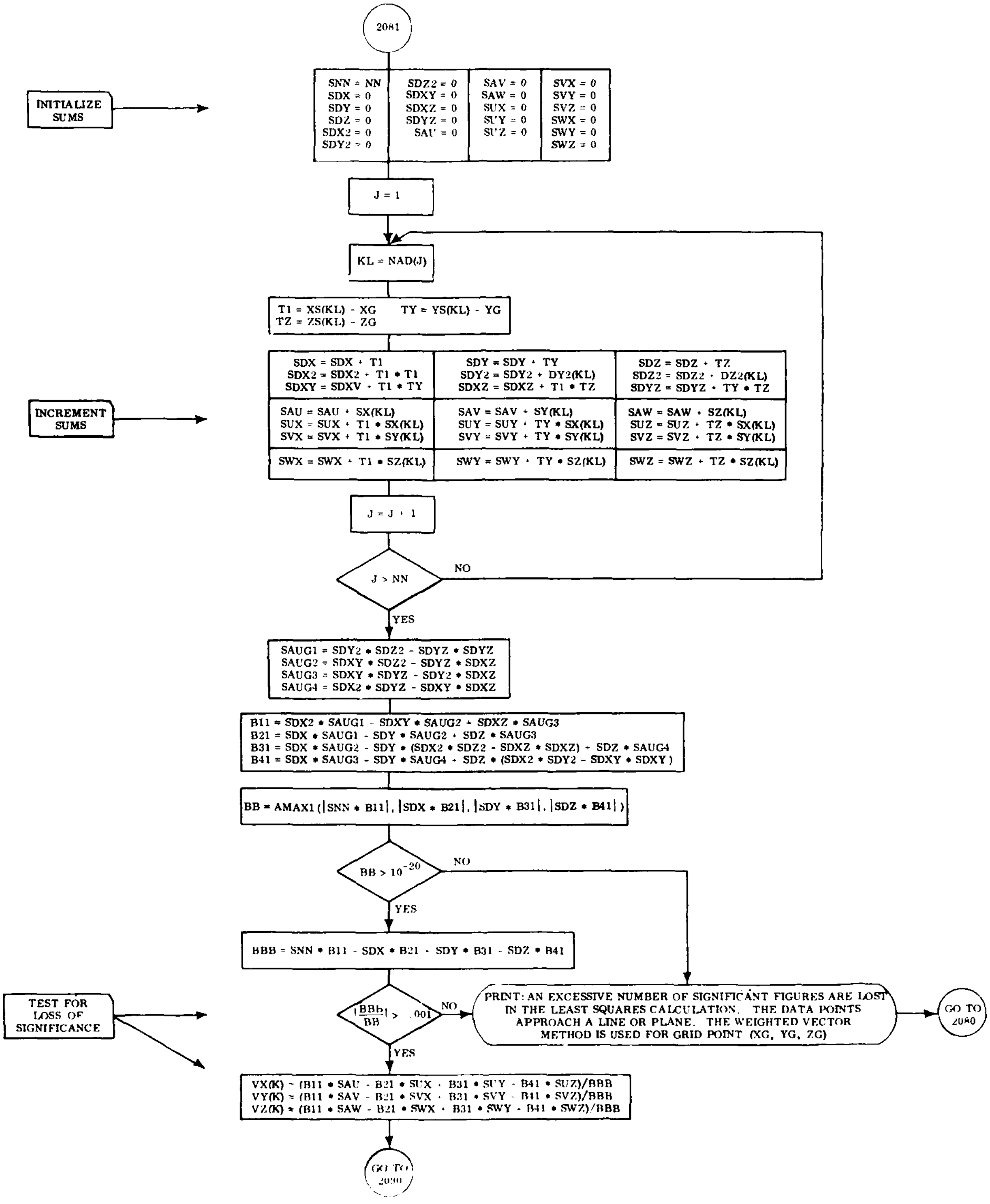
FC-8. (Continued) Detailed Flow Charts for Subroutine MKWIND


1158
SET NAD(J) = J FOR J = 1, JTOPV
NADT = 1
J = 1
T1 = (ZS(J) - ZG
T1 = T1 * T1
T2 = ALPHA2 - T1
COMPUTE SQUARE OF WEIGHTED DISTANCE BETWEEN J TH VECTOR AND POINT
T2 ≤ 0.0
YES
T2 = 0.0
NO
DZ2(J) = T2/(ALPHA2 + T1)
J = J + 1
J > JTOPV
NO
YES
200
J = 1
T1 = YS(J) - YG
DY2(J) = T1 • T1
COMPUTE SQUARE OF DISTANCE BETWEEN J-TH VECTOR AND GRID POINT
J = J + 1
J > JTOPV
NO
YES
2011
J = 1
T1 = (XS(J) - XG) * (XS(J) - XG) + DY2(J)
T2 = ((BETA2 - T1) / (BETA2 + T1)) * DZ2(J)
COMPUTE SQUARE OF DIAGONAL DISTANCE BETWEEN VECTOR AND GRID POINT
T2 ≤ GIB
YES
D2(J) = BIG
NO
D2(J) = 1.0/T2
I = J + 1
J > JTOPV
NO
YES
KL = NAD(NADT)
DM = D2(KL)
J = 1
KL = NAD(J)
DM - D2(KL)
DM = D2(KL)
NADT = J
+0
FIND MOST REMOTE OF THE NEAREST NN DATA VECTORS RECORD DISTANCE IN DM AND INDEX IN NADT
J = J + 1
J > NN
NO
YES
GO TO α
α
NN1 - JTOPV
-, 0
J = NN1
KL = NAD(J)
DM - D2(KL)
0, -
SCAN TO LOCATE ANY VECTOR NEARER THAN THE MOST REMOTE OF THE NEAREST NN
-
NTEMP = NAD(J)
NAD(J) = NAD(NADT)
NAD(NADT) = NTEMP
DM = D2(KL)
KKK = 1
KL = NAD(KKK)
RESET DM AND NADT TO INDICATE THE MOST REMOTE OF THE NEAREST NN VECTORS
DM - D2(KL)
-
DM = D2(KKK)
NADT = KKK
0, -
KKK = KKK + 1
KKK > NN
NO
YES
J = J + 1
J > JTOPV
NO
YES
2073
INCREMENT INDEX FOR STORING COMPUTED VECTORS
K = K + 1
NCODE - 4
ARE WE USING LEAST SQUARES METHOD?
-, -
0
WEIGHTED AVERAGE
GO TO 2080
GO TO 2081
LEAST SQUARES

(c)

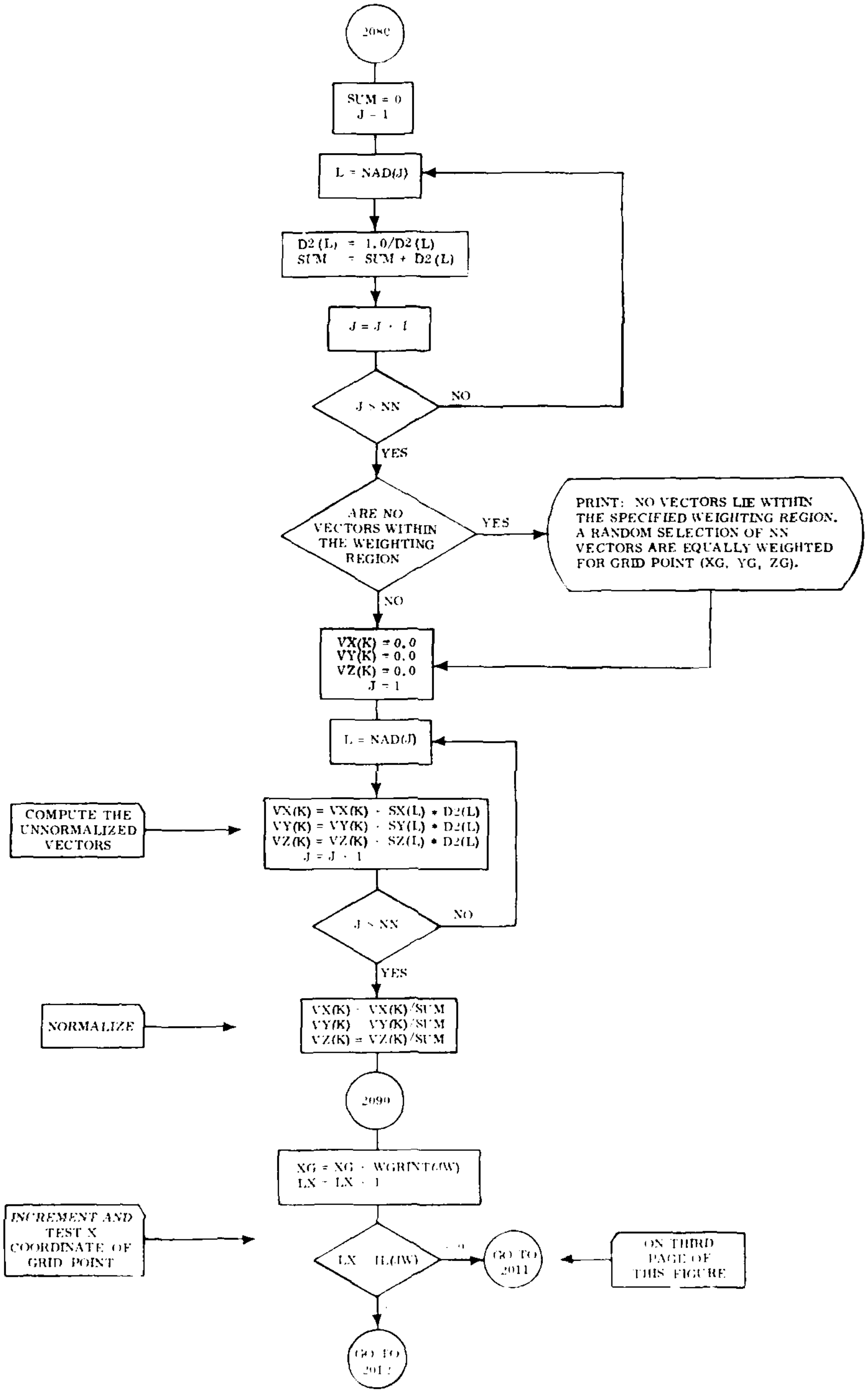
(d)

FC-8. (Continued) Detailed Flow Charts for Subroutine MKWIND


2081
INITIALIZE SUMS
SNN = NN
SDX = 0
SDY = 0
SDZ = 0
SDX2 = 0
SDY2 = 0
SDZ2 = 0
SDXY = 0
SDXZ = 0
SDYZ = 0
SAU = 0
SAV = 0
SAW = 0
SUX = 0
SUY = 0
SUZ = 0
SVX = 0
SVY = 0
SVZ = 0
SWX = 0
SWY = 0
SWZ = 0
J = 1
KL = NAD(J)
T1 = XS(KL) - XG
TY = YS(KL) - YG
TZ = ZS(KL) - ZG
INCREMENT SUMS
SDX = SDX + T1
SDX2 = SDX2 + T1 * T1
SDXY = SDXV + T1 * TY
SDY = SDY + TY
SDY2 = SDY2 + DY2(KL)
SDXZ = SDXZ + T1 * TZ
SDZ = SDZ + TZ
SDZ2 = SDZ2 + DZ2(KL)
SDYZ = SDYZ + TY * TZ
SAU = SAU + SX(KL)
SUX = SUX + T1 * SX(KL)
SVX = SVX + T1 * SY(KL)
SAV = SAV + SY(KL)
SUY = SUY + TY * SX(KL)
SVY = SVY + TY * SY(KL)
SAW = SAW + SZ(KL)
SUZ = SUZ + TZ * SX(KL)
SVZ = SVZ + TZ * SY(KL)
SWX = SWX + T1 * SZ(KL)
SWY = SWY + TY * SZ(KL)
SWZ = SWZ + TZ * SZ(KL)
J = J + 1
J > NN
NO
YES
SAUG1 = SDY2 * SDZ2 - SDYZ * SDYZ
SAUG2 = SDXY * SDZ2 - SDYZ * SDXZ
SAUG3 = SDXY * SDYZ - SDY2 * SDXZ
SAUG4 = SDX2 * SDYZ - SDXY * SDXZ
B11 = SDX2 * SAUG1 - SDXY * SAUG2 + SDXZ * SAUG3
B21 = SDX * SAUG1 - SDY * SAUG2 + SDZ * SAUG3
B31 = SDX * SAUG2 - SDY * (SDX2 * SDZ2 - SDXZ * SDXZ) + SDZ * SAUG4
B41 = SDX * SAUG3 - SDY * SAUG4 + SDZ * (SDX2 * SDY2 - SDXY * SDXY)
BB = AMAX1(|SNN * B11|, |SDX * B21|, |SDY * B31|, |SDZ * B41|)
BB > 10^-20
NO
YES
BBB = SNN * B11 - SDX * B21 - SDY * B31 - SDZ * B41
TEST FOR LOSS OF SIGNIFICANCE
|BBB/BB| > .001
NO
PRINT: AN EXCESSIVE NUMBER OF SIGNIFICANT FIGURES ARE LOST IN THE LEAST SQUARES CALCULATION. THE DATA POINTS APPROACH A LINE OR PLANE. THE WEIGHTED VECTOR METHOD IS USED FOR GRID POINT (XG, YG, ZG)
GO TO 2080
YES
VX(K) = (B11 * SAU - B21 * SUX + B31 * SUY - B41 * SUZ)/BBB
VY(K) = (B11 * SAV - B21 * SVX + B31 * SVY - B41 * SVZ)/BBB
VZ(K) = (B11 * SAW - B21 * SWX + B31 * SWY - B41 * SWZ)/BBB
GO TO 2090

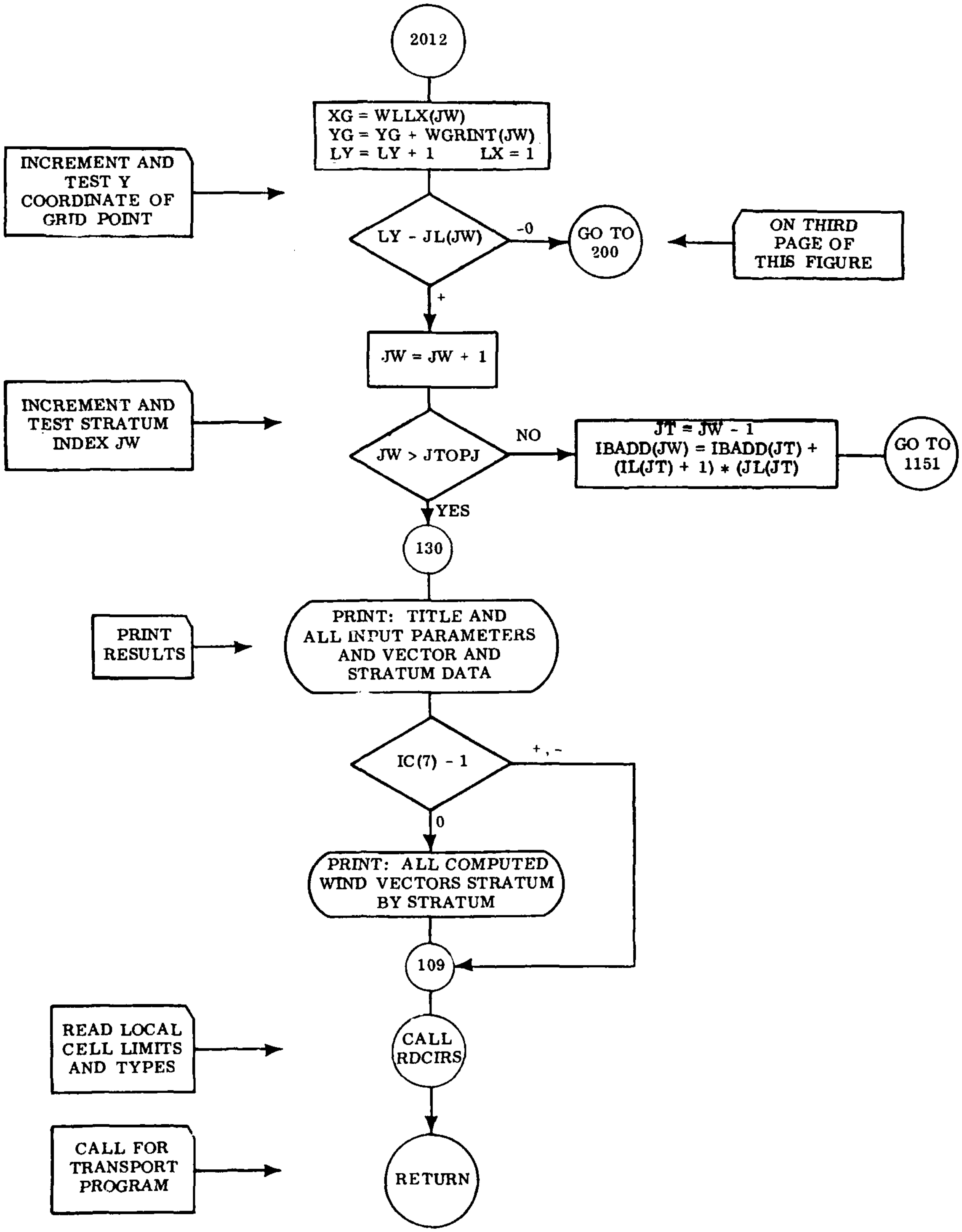
(e)

FC-8. (Continued) Detailed Flow Charts of Subroutine MKWIND


2080
SUM = 0
J - 1
L = NAD(J)
D2 (L) = 1.0/D2 (L)
SUM = SUM + D2 (L)
J = J · 1
J > NN
NO
YES
ARE NO VECTORS WITHIN THE WEIGHTING REGION
YES
PRINT: NO VECTORS LIE WITHIN THE SPECIFIED WEIGHTING REGION. A RANDOM SELECTION OF NN VECTORS ARE EQUALLY WEIGHTED FOR GRID POINT (XG, YG, ZG).
NO
VX(K) = 0.0
VY(K) = 0.0
VZ(K) = 0.0
J = 1
L = NAD(J)
COMPUTE THE UNNORMALIZED VECTORS
VX(K) = VX(K) · SX(L) * D2(L)
VY(K) = VY(K) · SY(L) * D2(L)
VZ(K) = VZ(K) · SZ(L) * D2(L)
J = J · 1
J > NN
NO
YES
NORMALIZE
VX(K) · VX(K)/SUM
VY(K) VY(K)/SUM
VZ(K) = VZ(K)/SUM
2090
XG = XG · WGRINT(JW)
LX = LX · 1
INCREMENT AND TEST X COORDINATE OF GRID POINT
LX IL(JW)
GO TO 2011
ON THIRD PAGE OF THIS FIGURE
GO TO 2012

(f)

FC-8. (Continued) Detailed Flow Charts of Subroutine MKWIND


2012
XG = WLLX(JW)
YG = YG + WGRINT(JW)
LY = LY + 1 LX = 1
INCREMENT AND TEST Y COORDINATE OF GRID POINT
LY - JL(JW)
-0
GO TO 200
ON THIRD PAGE OF THIS FIGURE
+
JW = JW + 1
INCREMENT AND TEST STRATUM INDEX JW
JW > JTOPJ
NO
JT = JW - 1
IBADD(JW) = IBADD(JT) + (IL(JT) + 1) * (JL(JT)
GO TO 1151
YES
130
PRINT RESULTS
PRINT: TITLE AND ALL INPUT PARAMETERS AND VECTOR AND STRATUM DATA
IC(7) - 1
+, -
0
PRINT: ALL COMPUTED WIND VECTORS STRATUM BY STRATUM
109
READ LOCAL CELL LIMITS AND TYPES
CALL RDCIRS
CALL FOR TRANSPORT PROGRAM
RETURN

(g)

FC-8. (Continued) Detailed Flow Charts of Subroutine MKWIND

In the beginning the parameters ENDTIM, ALPHA, BETA, NN, and NCODE are read from the IBSYS input tape. If NN is zero or negative, an error stop is printed and the program terminates;* with NN positive, the program transfers control to 2041 where it begins reading the deck of data in which the user specifies the wind-field subdivision structure that he wishes the program to use. This reading operation continues until a card having the value 999999.0 in the field BOTHIT(J) is encountered. If such a card is not encountered before more than NSTRAT (specified in LINK6) cards have been read, an error comment will be written and processing will be continued. When the deck ending card (BOTHIT(J) = 999999.0) is encountered, the variable JTOPJ is set to the number of stratum specifications that have been read. At statement 1054 the data just read are arranged into ascending order of stratum base altitude (BOTHIT(J)) by a pair comparison replacement sort. If during the sort two specifications are found for the same altitude, a comment is printed and an error stop occurs.

When the program reaches statement number 1055 the sort of stratum specifications is complete and the program begins to read a deck of wind vector data. This read operation is of the same form as the read of stratum specifications, but the count of data vectors is recorded in the variable JTOPV. If at the end of the vector-read operation the number of vectors read does not exceed NN, the specified number of nearest data vectors to be used in the computation of each wind cell vector, NN is reset to JTOPV and the computations will continue after a comment is written.

*The use of NN with the preferential weighting method is somewhat redundant in that the weighting procedure automatically limits consideration to only those observations that lie within specified distances, horizontal and vertical distances being specified independently of the wind-field grid points. Normally one should specify NN to equal the total number of input wind vector observations when the preferential weighting method is used. In any case, only the NN wind vectors closest to each grid point will be used in determining each wind field vector.

Continuing from statement 106, the program determines if $0 < \text{NCODE} \leq 6$ and, if so, branches on NCODE to make preparations for further processing by the chosen computation method (see flow chart FC-9 and Table 8). After all transfers are made to an available computation method via NCODE, control eventually returns to statement 115.

At 115 initializations are made for a loop that will fill in sequentially all of the wind cells of the specified strata and will record the vector values in the arrays VX(J), VY(J), and VZ(J). The storage index of the first entry in the wind-field description arrays for the first stratum is set at 1 (i.e., IBADD(1) = 1), the stratum index JW is set at 1 to designate the first and lowest stratum, and the vector storage index, K, is initialized at 0.

At 1151 IL(JW) and JL(JW), the number of wind cells in stratum JW in the X and Y directions, respectively, are computed. The constant 0.9999999 is added before truncation of the floating point value to an integer to insure that the cells will always cover the complete area specified by the user. Next, further initialization occurs and the grid point coordinates XG, YG, and ZG are set at the center of the first cell of the stratum. Note that special treatment must be given to the Z coordinate of both the top and bottom strata.

At 1158 the program begins to set up the array NAD, which is used to store address indices of wind data vectors that are nearest neighbors to a particular wind field grid point. It first sets all NAD(J) = J, J = 1, JTOPV, to provide indices for the full set of data points and to provide an initial set of nearest data points. Note that in the beginning the NAD do not reference data vectors in order of increasing distance from the grid point (XG, YG, ZG), but merely provide an initial input to a sort procedure that will provide such an ordering. Initially, we set NADT, the index of the NAD representing the data vector which is the most remote (from the grid point) of the nearest NN vectors, at 1, since prior to the first pass through the distance sorter all NN data vectors are equally likely to be the most remote of the set.

Next, in three DO loops ending at 199, 201, and 202 we compute weighting factors related to the vertical and horizontal distances between the current grid point and each data vector point, and store the result as a measure of remoteness in the array D2(J) which is parallel to the data vector arrays. We attempt to minimize computation by keeping weighting factor components in parallel arrays DY2 and DZ2 during the evaluation of a wind field.

After 202 we find the address of and distance to the most remote point (from the grid point) of the currently specified NN "nearest" data points. (These are the points whose addresses (indices) are given by NAD(1) through NAD(NN). This maximum distance is stored in the word DM and NADT is set such that DM = D2(NAD(NADT)).

At 2072 we may scan the data vectors that are not within the set of nearest NN to ascertain that there is no vector nearer than the most remote of the nearest NN. If one is found, its address must be inserted in the place of the most remote and adjustments made to NADT and DM. (This somewhat obscure procedure is intended to achieve efficiency by making extensive use of the strong correlation that will exist between the interpoint distances in the array D2 as the calculation progresses from one grid point evaluation to the next.) At the end of this procedure (after 2073) the nearest NN data vectors have been located and their addresses are recorded in NAD(J), J = 1, NN.

The grid data storage index K is next incremented and a second branch is made on the basis of NCODE.

If NCODE = 4, we branch to the least-squares method which uses the NN nearest data points under the restraint that NN $\geq$ 4. Rectilinear coordinates of the points are determined with respect to the grid point at which we wish to calculate the wind field. Next, the elements of the normal equations matrix are computed and the complementary minors B11, B21, B31, and B41 are determined. If BB, the absolute value of the largest of the four products of the cofactors times their corresponding matrix elements, is not less than 10^{-20}, the determinant BBB is computed and the ratio $\left|\frac{BBB}{BB}\right|$ is found. If BB is less than 10^{-20} or the ratio $\left|\frac{BBB}{BB}\right|$ is less than 10^{-3}, an excessive number of significant figures are lost in the least-squares calculation for this particular grid point (i.e., the normal equations matrix is essentially singular), and the code prints this information and then branches to the preferential weighting method (as though NCODE = 1). If neither of these cases occurs, the wind velocity vectors are computed an:l stored using index K.

If the preferential weighting method is to be used (NCODE = 1), a transfer is made to 2080 where weighting factors are computed and summed for the NN nearest data vectors. Next (after 214), the three vector components are computed as a weighted average of the vectors at the NN nearest data points and the results are stored in the arrays VX, VY, and VZ under the index K.

The least squares and preferential weighting methods converge again at statement 2090 where the indexing and control scheme begins. First, the X coordinate of the current grid point is incremented, and if the new grid point is still within the desired wind field, the program returns to 2011 to begin the evaluation of its vector. If the new X coordinate is beyond the wind-field range, X is reset and Y is incremented and tested. If both X and Y end up beyond the range of interest, the program moves on to the next higher stratum. When all strata have been evaluated in full the program branches to 130 where all input data are printed, and if desired (IC(7) = 1), *all computed wind cell vectors* are also printed. Finally at 109 a call is made to subroutine RDCIRS which reads a set of data describing the limits of all local circulation cells and the types of circulation systems within them. Upon return from RDCIRS, MKWIND returns to the monitor so that transport may be continued using the newly updated wind field descripti·jn.

Subroutine LINK7 (FC-9 and FC-10)

This subroutine is the primary transport program. It accepts a tape of transportable particles and transports them, stopping only when it has no more particles to transport or when a new version of the wind-field description must be prepared. The fi·rst action of LINK7 is to interrogate the input parameter IC(6) (see Table 6) to ascertain whether the transport traces have been requested. If IC(6) < 1, no traces are printed. If IC(6) = 1, the complete in-core particle arrays are printed after each block of new particles is read in from tape IPARIN. Each line of this output consists of XP, YP, ZP, TP, PS, and FMAS. If IC(6) > 1, at the beginning of the main transport loop this same information is printed for each particle in turn, and in addition after each transport increment the quantities XP, YP, ZP, TP, TSM, NTI, NG, NTO, NW, NLOST, and IR (see the LINK5 glossary for definition of these quantities) are printed for each particle. In the execution of the Transport Module LINK7 is always preceded by a call to LINK6, the wind-field description generator program. Since the data peculiar to each existing local circulation system (as defined by RDCIRS which is called by LINK6) must also be updated before transport begins, LINK7 first transfers to each of the required local circulation codes to cause them to read their data. If there are no local circulation systems in use, or after reading the data for the required local circulation codes, LINK7 continues at statement number 510. There, assignments are made for parameters IT and ITT according to the value of IC(1) to control the transport of particles as they approach the topography (see Table 6).

Next, at 1000 the program makes preparations to enter the main transport loop. IS and IF are set for use as particle index limits of the main transport loop. If JTIME1 is zero a regular entrance is being made, but if JTIME1 is negative, there may be transportable particles in the particle arrays left over from the preceding pass (prior to the most recent updating of the wind field). In the latter case the main transport loop is entered with index limits set to cover the full particle array so that all left-over transportable particles will be dealt with.

If JTIME1 is zero or positive (no particles remain at the time boundary), the program at statement 1112 begins processing transportable particles from tape IPARIN. Note that the logical tape number recorded in parameter IPARIN is not always the number of the unit on which the data was originally received from LINK4. IPARIN always identifies a tape containing transportable particles, but these may be either the original input from LINK4 or a recirculation of particles that were written onto some one of the secondary memory units IPAROT, IOWIND, or IOTOPO. At 1112 LINK7 reads a block count, N, from IPARIN; if N is positive and N particle descriptions can fit into the particle arrays, subroutine DUMPP is called to prepare a place for the N particles. The loop index limits are reset to cause processing of the incoming N particles and the N particles are read from IPARIN. Finally, NFREE, the count of empty spaces in the particle arrays, is decreased by N and control is transferred to 1001 where the main transport loop begins. In the event that the block count was zero, the end of the set of transportable particles on IPARIN has been reached and a transfer is made to 100 where preparations are made to either recirculate data from secondary memory tapes or transfer to the transport executive (LINK5). At this point LINK5 will either call for updating of the wind field or for the Output Processor Module.

Continuing this explanation at statement 100 we see that if off-topo particles exist (JTOP1≠0), the program selects the next needed topo file, fetches it from IHTOPO, and subsequently returns to the main transport loop (1001) to make use of the newly acquired topo data.

At 104 a similar treatment is given to particles that may have gone beyond the in-core wind field. However, since currently existing wind field programs do not make use of a tape wind field file, the code beginning at statement 130 will not be executed.

At 200 preparations are made to return to the transport executive where a call is provided for either the output processor or the wind-field program.

The main transport loop (between statement numbers 1001 and 160) uses the index J to identify the current particle description. It begins by determining if the current (Jth) particle is to be transported. To be transportable it must be identified by a positive FMAS(J) and O < TP(J) < TLIMIT; the program avoids all untransportable particles by transferring immediately to the loop control point at 160 whenever one is encountered.

At 195 NLOCIR, the number of local circulation systems in use, is tested. If any are in use, the Jth particle is tested to see if it is within or above any local cell, but if there are none in use, this test is avoided. If a particle is found to be in or above any local cell, LOTRAN is called to transport the particle until it passes beyond the cell's vertical boundary planes. Since a particle may pass out of one local cell and immediately into another, control cannot be returned to the main body of the transport loop (at 1950) until it has been ascertained that the particle is no longer within or above any of the local cells.

At 1950 arguments are set for a call to subroutine GETWND at 1961. GETWND gets the macrowind-field vector that applies at the point whose coordinates are in arguments XX, YY, ZZ. If upon return the index JWAD is set negative, the needed macrowind data is not available and the particle must be considered lost to the computation. However, if JWAD is positive, a correct retrieval has been accomplished and the program continues to 196.

At 196 the particle settling rate is computed for the current particle by the call to FALRAT and VPZ is set as the net vertical particle velocity component. Next, distances are computed from the particle position to each of the vertical planes that bound the macrowind cell containing the particle. Time of flight is then computed to the north-south and east-west boundary planes and also to the horizontal plane which would be first encountered.

At 1711 the time of flight to the first intersection with a local circulation cell is computed, but note that if NLOCIR (the number of local cells in use) is zero much code is avoided and a transfer is made directly to 172. In the event that intersections with local cells must be sought, a DO loop sequentially computes the time of intersection to each of the defined cells keeping track of the time of flight to the first intersection (if there is one) in variable CIRMIN.

At 172 the program selects the time of flight to the first of all intersections with boundary planes; if that time of flight is excessively small, special steps must be taken (at 1811) to assure that program efficiency is not lost. Asymptotic approaches to boundaries are avoided by never using a time step smaller than EPSIL. Oscillations at boundaries are avoided by treating the occurrence of two sequential, excessively small time steps as a sign of oscillation and by subsequently avoiding movements to or from the plane of oscillation.

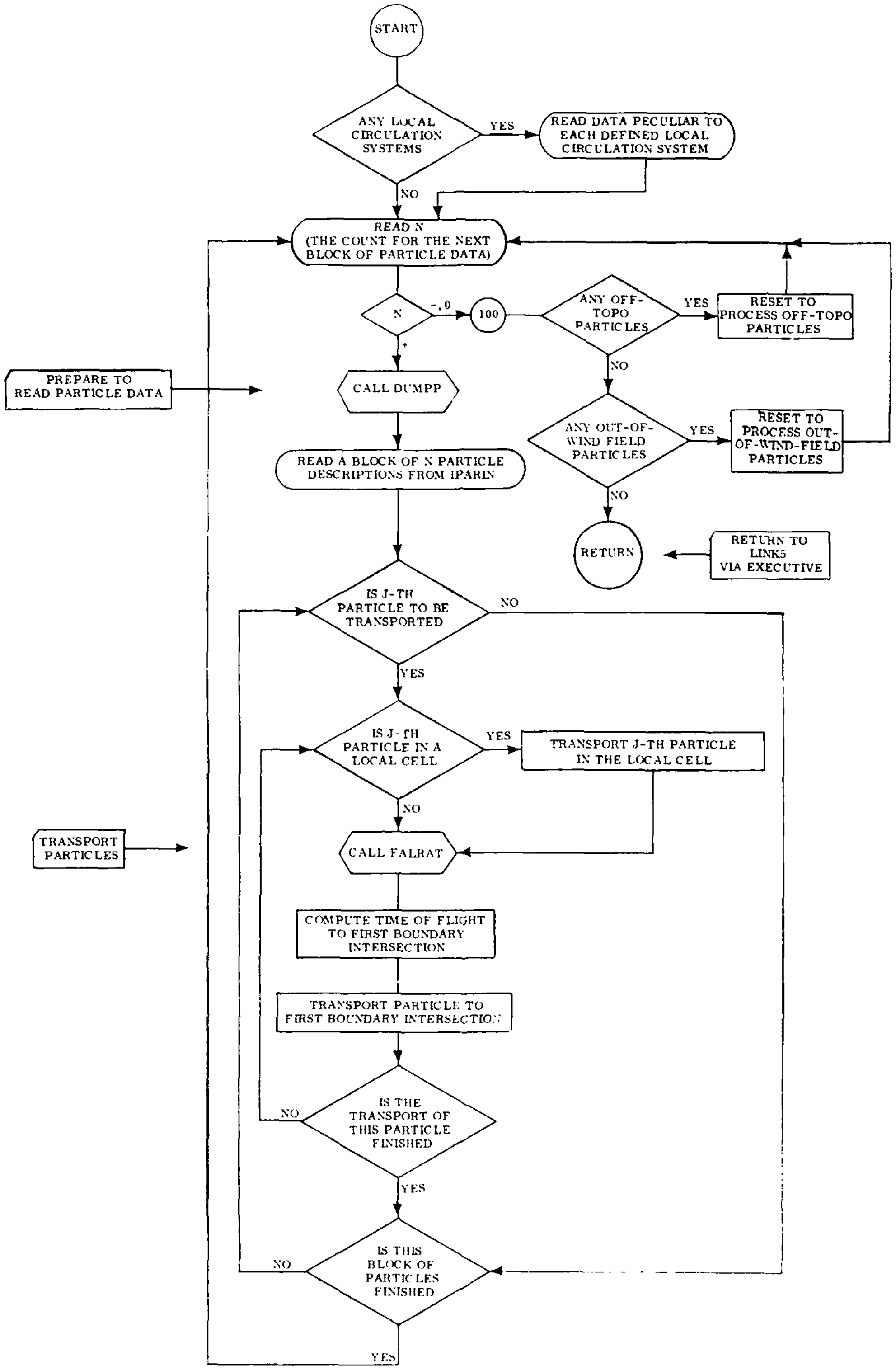
Continuing at 3067 a comparison of particle altitude and maximum topo height is made and if the particle is above TTOPO, simple linear transport occurs. However, if particle altitude is below TTOPO, a special loop beginning at 1814 is used to transport the particle by constant time steps (DTMAC) for the interval TSM or until impact on topography occurs. It should be noted that the main transport loop never moves any particle descriptions within the particle arrays. It does, however, mark the status of particles within the arrays using the sign of parameter FMAS(J) and the sign and value of TP(J) in accordance with the conventions described in Table 2.

Subroutine GETWND(XX, YY, ZZ, JWAD, JW) (FC-11)

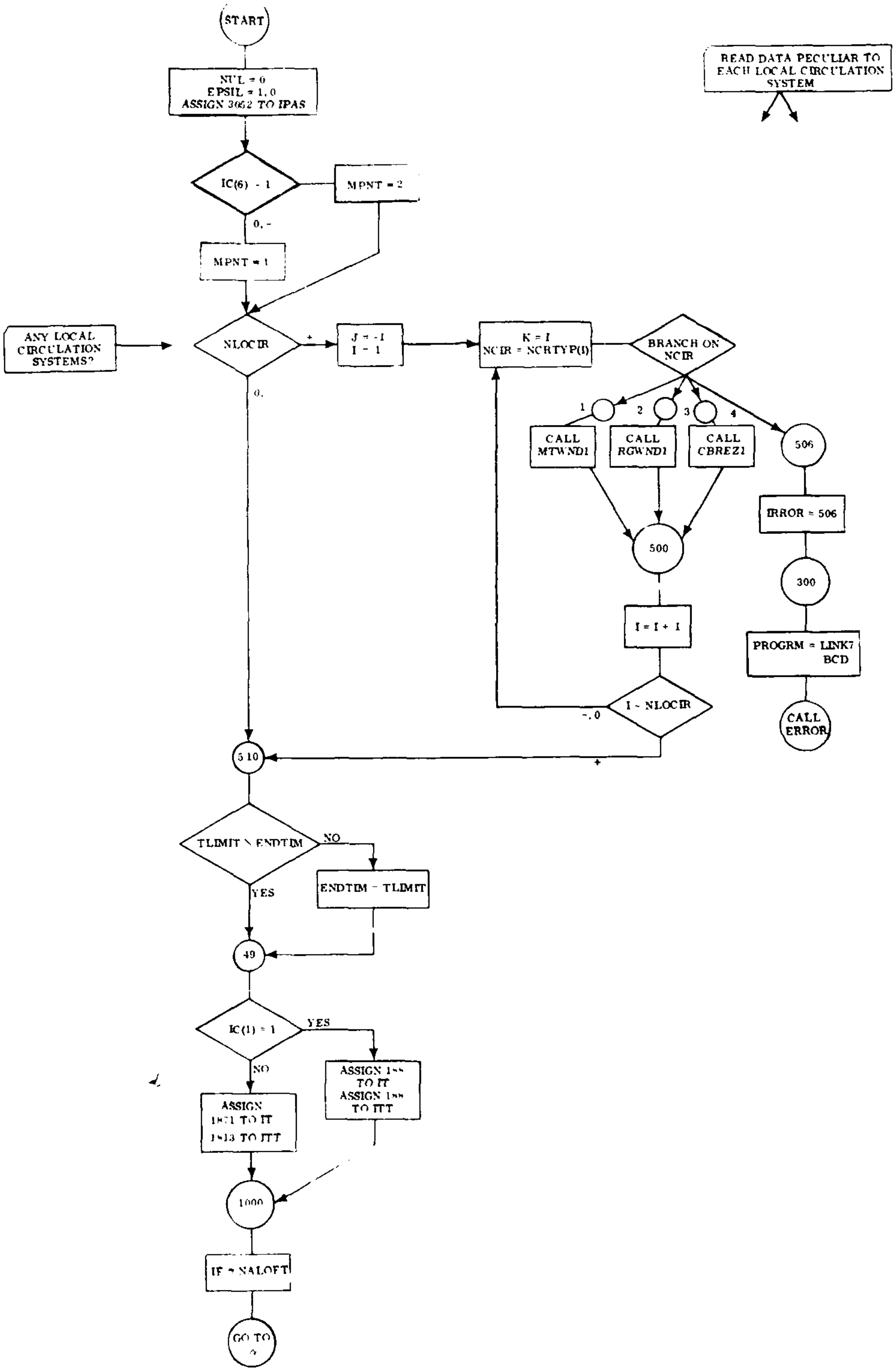
The purpose of this program is to determine the index to be used for retrieving the macrowind vector that applies at a particle position point XX, YY, ZZ. The desired index is stored in the argument JWAD upon return. JWAD is set negative in the event that the point XX, YY, ZZ is outside the volume for which the macrowind field has been specified.

The computation of index JWAD consists of two parts: first, the computation of JW, the index of the wind stratum containing the point; and second, the actual computation of the retrieval index JWAD using information describing the data structure of the JWth stratum. In the event that it is known that the value of the JW last computed is still valid, the computation of JW can be avoided. The calling program must only set the sign of the valid JW negative to cause GETWND to avoid recomputing it.

The execution of GETWND begins by testing the sign of argument JW. If the sign is negative, it is set positive and a transfer is made to statement 270 where JW is used to compute JWAD. If JW is nonnegative, a two-boundaried binary search is used to set JW. In that search JT is initialized as the index of the top wind layer and JW is initialized as the index of the bottom wind layer of the whole macrowind field. A test index (JTEST) is computed as the (truncated) mean between JT and JW and the program determines whether the point is above or below the bottom height (BOTHIT(JTEST)) of the test index's wind layer. If the particle is above the bottom of layer JTEST, the bottom index JW is reset equal to JTEST to indicate that the particle has been found to lie in some layer from JTEST(JW) through JT. Had the particle been below the test layer, the top index would have been reset to equal the test index. The algorithm proceeds by converging iteratively on the layer containing the particle and exits when JT and JW are separated by unity at which point the particle must be within the JWth layer.

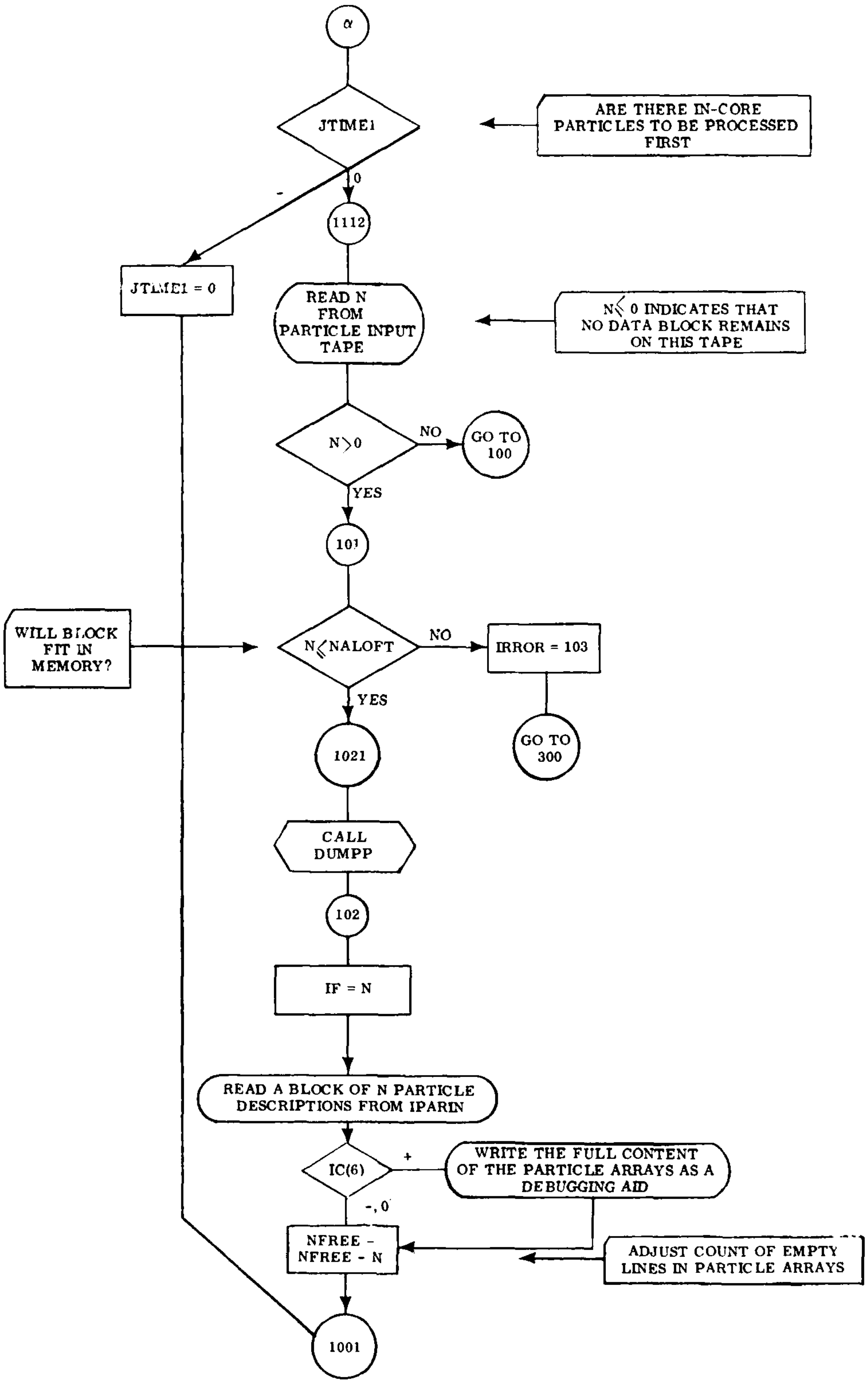

START
ANY LOCAL CIRCULATION SYSTEMS
YES
READ DATA PECULIAR TO EACH DEFINED LOCAL CIRCULATION SYSTEM
NO
READ N (THE COUNT FOR THE NEXT BLOCK OF PARTICLE DATA)
N
-, 0
100
ANY OFF-TOPO PARTICLES
YES
RESET TO PROCESS OFF-TOPO PARTICLES
NO
+
PREPARE TO READ PARTICLE DATA
CALL DUMPP
ANY OUT-OF-WIND FIELD PARTICLES
YES
RESET TO PROCESS OUT-OF-WIND-FIELD PARTICLES
READ A BLOCK OF N PARTICLE DESCRIPTIONS FROM IPARIN
NO
RETURN
RETURN TO LINK5 VIA EXECUTIVE
IS J-TH PARTICLE TO BE TRANSPORTED
NO
YES
IS J-TH PARTICLE IN A LOCAL CELL
YES
TRANSPORT J-TH PARTICLE IN THE LOCAL CELL
NO
TRANSPORT PARTICLES
CALL FALRAT
COMPUTE TIME OF FLIGHT TO FIRST BOUNDARY INTERSECTION
TRANSPORT PARTICLE TO FIRST BOUNDARY INTERSECTION
NO
IS THE TRANSPORT OF THIS PARTICLE FINISHED
YES
NO
IS THIS BLOCK OF PARTICLES FINISHED
YES

FC-9. General Flow Chart for Subroutine LINK7



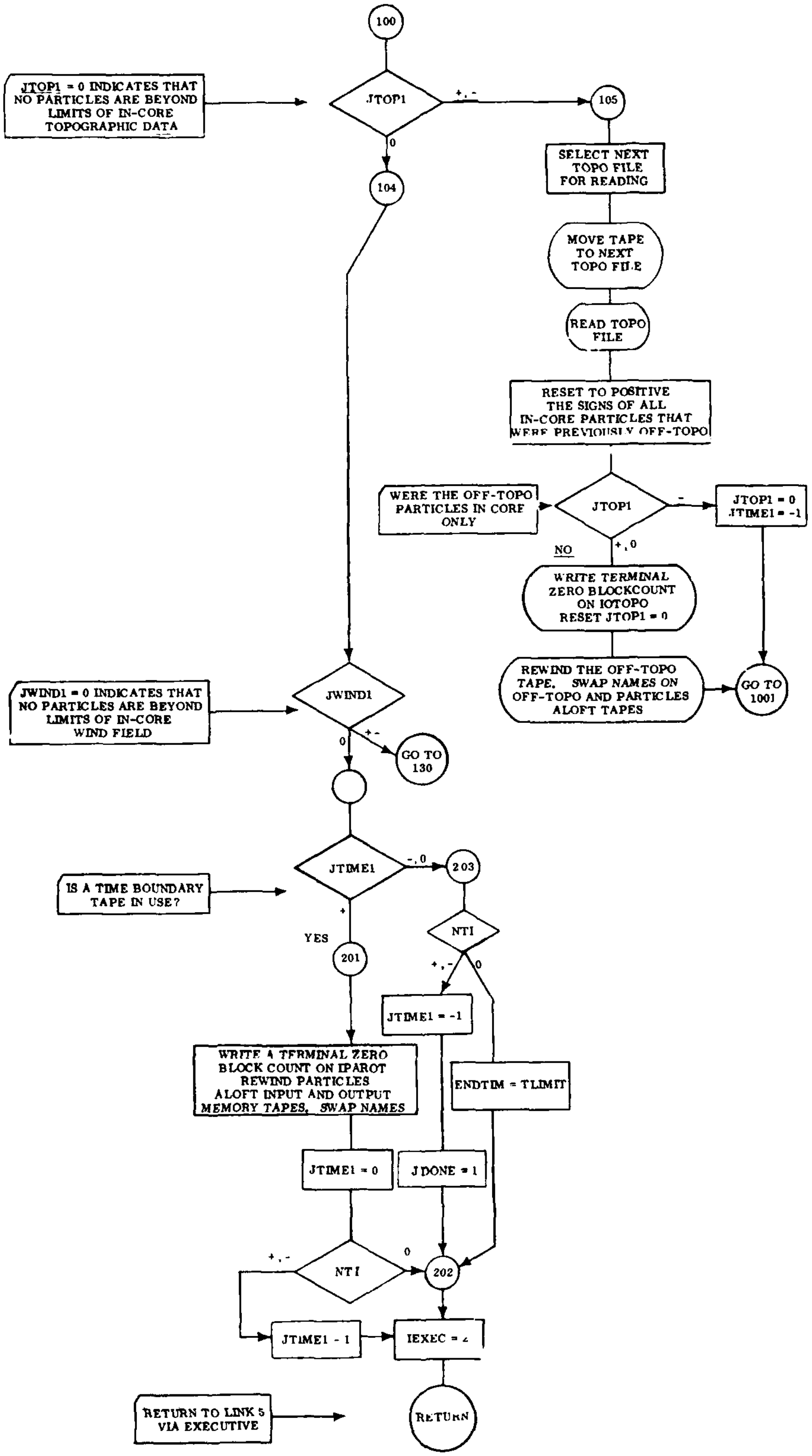
(a)

FC-10. Detailed Flow Charts for Subroutine LINK7


α
JTIME1
ARE THERE IN-CORE PARTICLES TO BE PROCESSED FIRST
-
0
1112
JTIME1 = 0
READ N FROM PARTICLE INPUT TAPE
N≤ 0 INDICATES THAT NO DATA BLOCK REMAINS ON THIS TAPE
N>0
NO
GO TO 100
YES
101
WILL BLOCK FIT IN MEMORY?
N≤NALOFT
NO
IRROR = 103
GO TO 300
YES
1021
CALL DUMPP
102
IF = N
READ A BLOCK OF N PARTICLE DESCRIPTIONS FROM IPARIN
IC(6)
+
WRITE THE FULL CONTENT OF THE PARTICLE ARRAYS AS A DEBUGGING AID
-, 0
NFREE - NFREE - N
ADJUST COUNT OF EMPTY LINES IN PARTICLE ARRAYS
1001

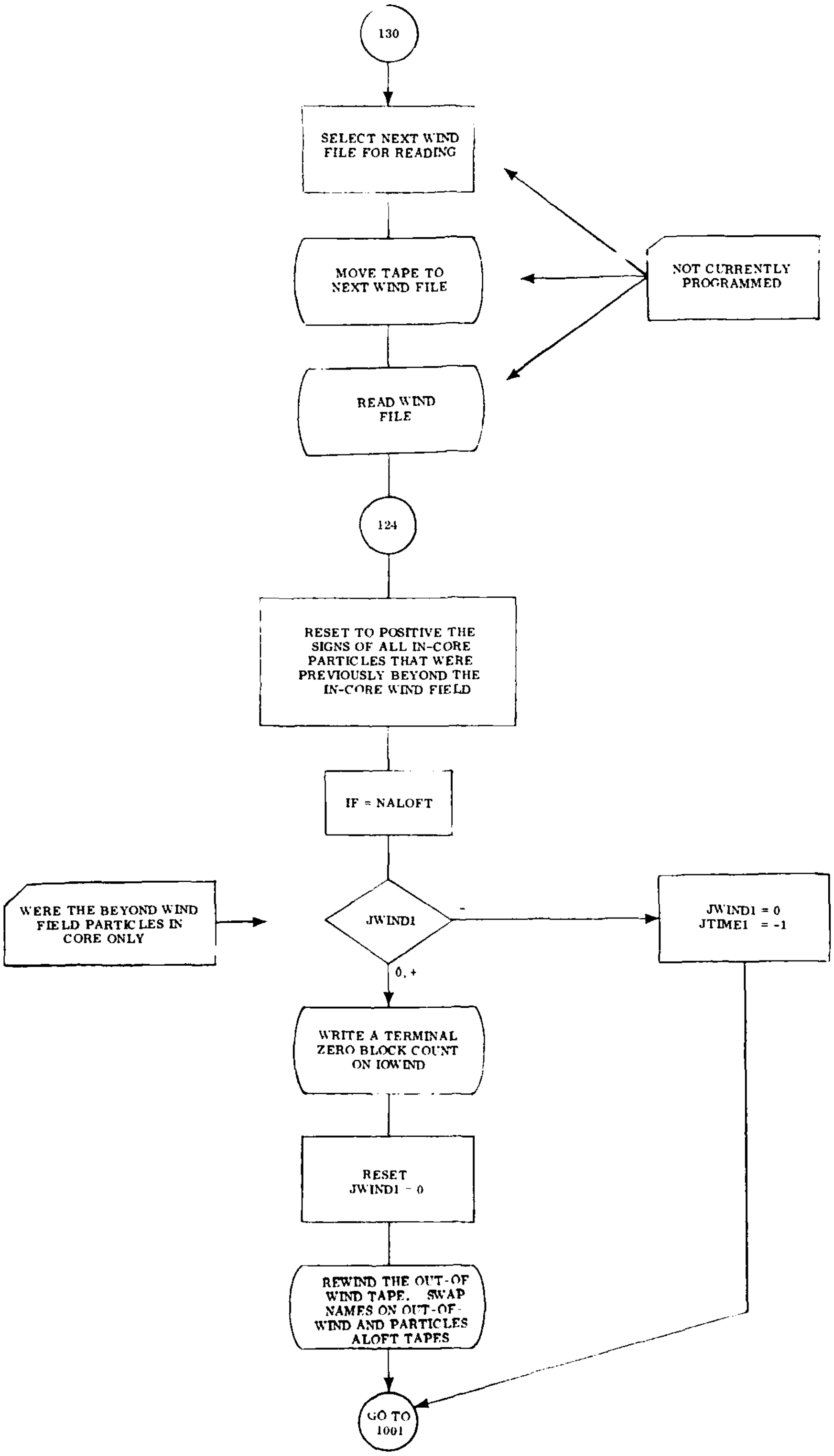
(b)

FC-10. (Continued) Detailed Flow Charts for Subroutine LINK7


100
JTOP1 = 0 INDICATES THAT NO PARTICLES ARE BEYOND LIMITS OF IN-CORE TOPOGRAPHIC DATA
JTOP1
+, -
0
105
104
SELECT NEXT TOPO FILE FOR READING
MOVE TAPE TO NEXT TOPO FILE
READ TOPO FILE
RESET TO POSITIVE THE SIGNS OF ALL IN-CORE PARTICLES THAT WERE PREVIOUSLY OFF-TOPO
WERE THE OFF-TOPO PARTICLES IN CORE ONLY
JTOP1
-
JTOP1 = 0
JTIME1 = -1
NO
+, 0
WRITE TERMINAL ZERO BLOCKCOUNT ON IOTOPO RESET JTOP1 = 0
REWIND THE OFF-TOPO TAPE. SWAP NAMES ON OFF-TOPO AND PARTICLES ALOFT TAPES
GO TO 1001
JWIND1 = 0 INDICATES THAT NO PARTICLES ARE BEYOND LIMITS OF IN-CORE WIND FIELD
JWIND1
0
+-
GO TO 130
JTIME1
-, 0
203
IS A TIME BOUNDARY TAPE IN USE?
+
YES
201
NTI
+, -
0
JTIME1 = -1
ENDTIM = TLIMIT
WRITE A TERMINAL ZERO BLOCK COUNT ON IPAROT REWIND PARTICLES ALOFT INPUT AND OUTPUT MEMORY TAPES, SWAP NAMES
JTIME1 = 0
JDONE = 1
+, -
NTI
0
202
JTIME1 - 1
IEXEC = 2
RETURN TO LINK 5 VIA EXECUTIVE
RETURN

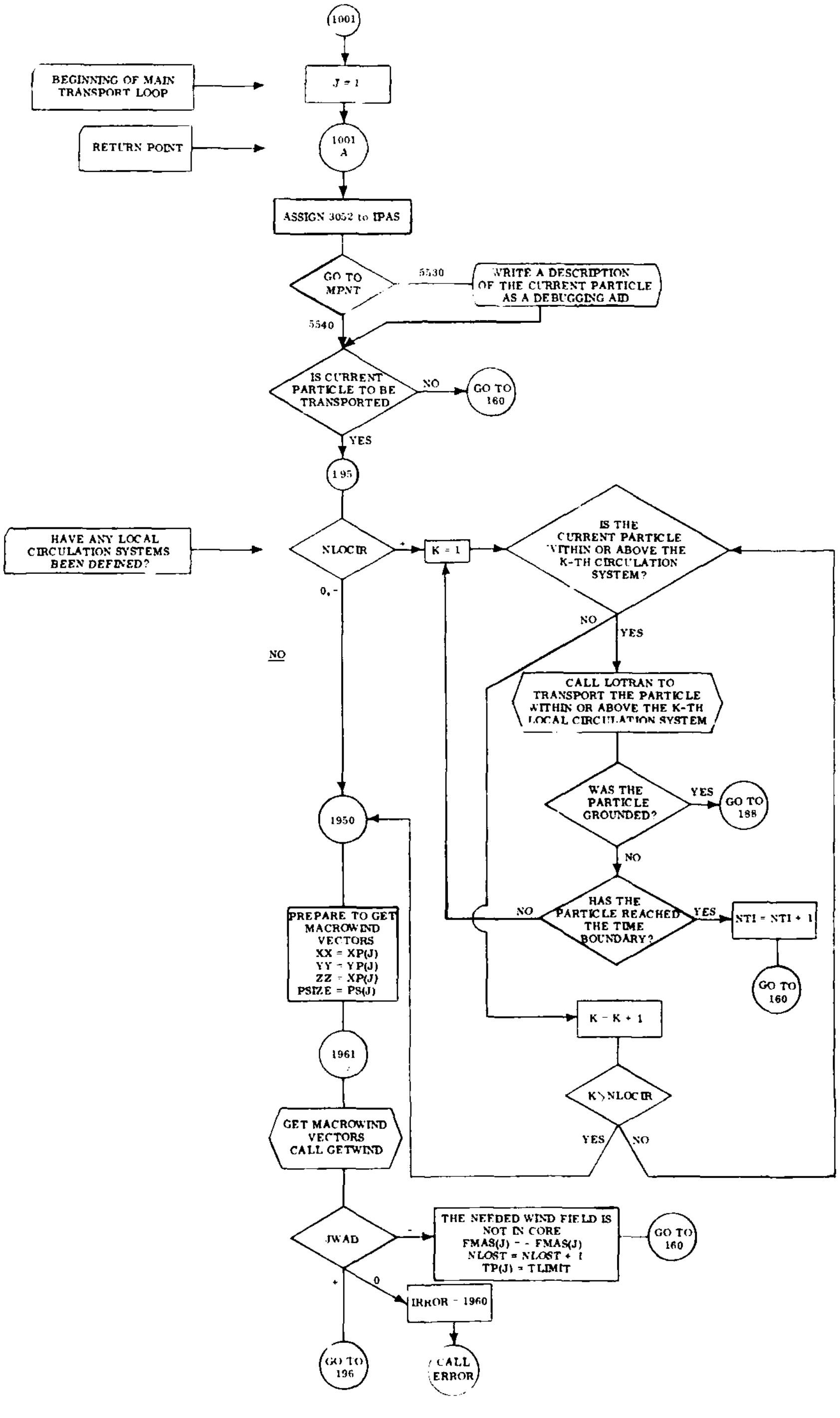
(c)

FC-10. (Continued) Detailed Flow Charts for Subroutine LINK7


130
SELECT NEXT WIND FILE FOR READING
MOVE TAPE TO NEXT WIND FILE
READ WIND FILE
NOT CURRENTLY PROGRAMMED
124
RESET TO POSITIVE THE SIGNS OF ALL IN-CORE PARTICLES THAT WERE PREVIOUSLY BEYOND THE IN-CORE WIND FIELD
IF = NALOFT
WERE THE BEYOND WIND FIELD PARTICLES IN CORE ONLY
JWIND1
-
0, +
JWIND1 = 0
JTIME1 = -1
WRITE A TERMINAL ZERO BLOCK COUNT ON IOWIND
RESET JWIND1 = 0
REWIND THE OUT-OF WIND TAPE. SWAP NAMES ON OUT-OF-WIND AND PARTICLES ALOFT TAPES
GO TO 1001

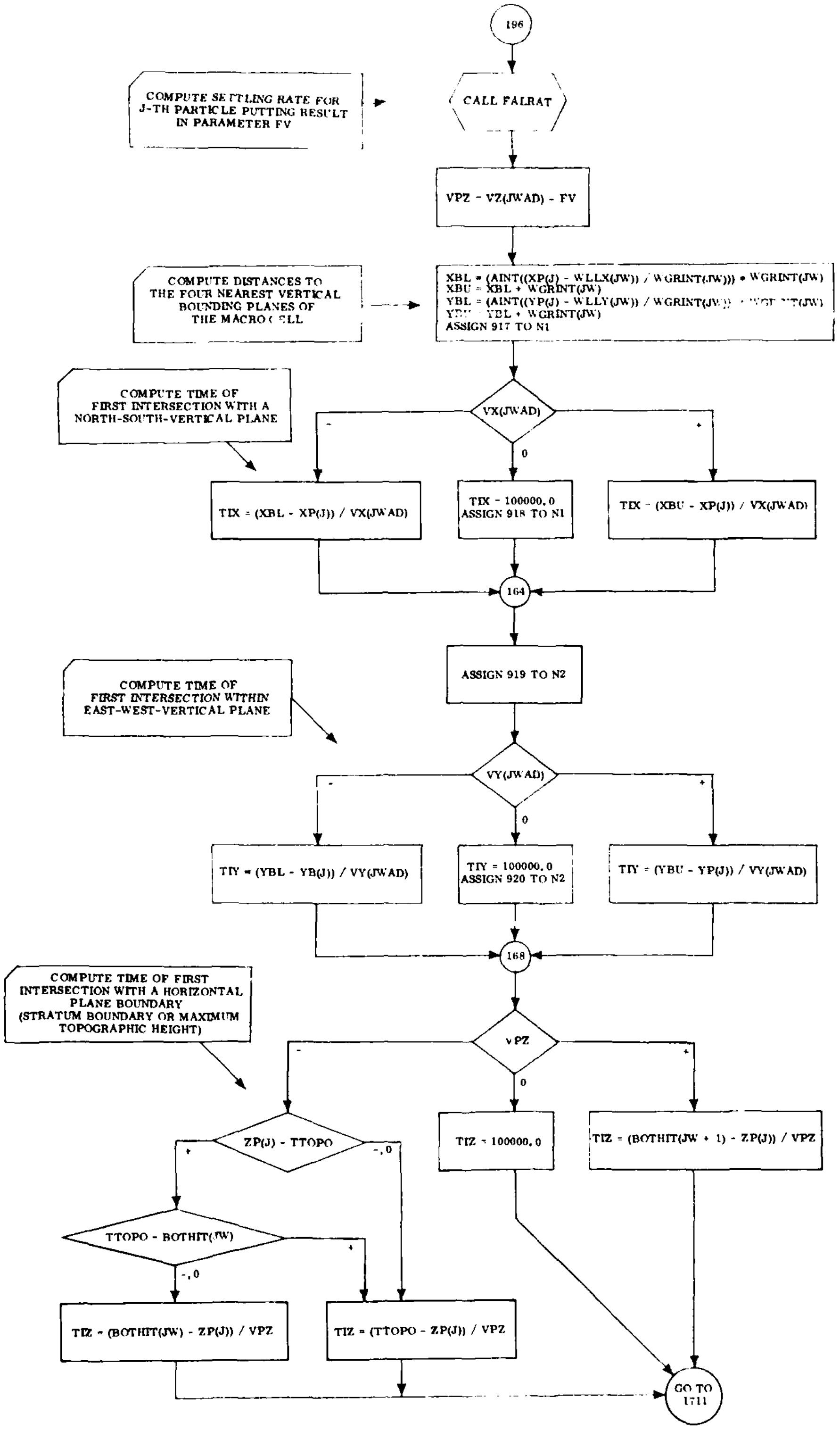
(d)

FC-10. (Continued) Detailed Flow Charts for Subroutine LINK7


1001
BEGINNING OF MAIN TRANSPORT LOOP
J = 1
RETURN POINT
1001 A
ASSIGN 3052 to IPAS
GO TO MPNT
5530
WRITE A DESCRIPTION OF THE CURRENT PARTICLE AS A DEBUGGING AID
5540
IS CURRENT PARTICLE TO BE TRANSPORTED
NO
GO TO 160
YES
195
HAVE ANY LOCAL CIRCULATION SYSTEMS BEEN DEFINED?
NLOCIR
+
0, -
NO
K = 1
IS THE CURRENT PARTICLE WITHIN OR ABOVE THE K-TH CIRCULATION SYSTEM?
NO
YES
CALL LOTRAN TO TRANSPORT THE PARTICLE WITHIN OR ABOVE THE K-TH LOCAL CIRCULATION SYSTEM
WAS THE PARTICLE GROUNDED?
YES
GO TO 188
NO
HAS THE PARTICLE REACHED THE TIME BOUNDARY?
NO
YES
NTI = NTI + 1
GO TO 160
1950
PREPARE TO GET MACROWIND VECTORS
XX = XP(J)
YY = YP(J)
ZZ = XP(J)
PSIZE = PS(J)
K = K + 1
K > NLOCIR
YES
NO
1961
GET MACROWIND VECTORS CALL GETWIND
JWAD
-
THE NEEDED WIND FIELD IS NOT IN CORE
FMAS(J) = - FMAS(J)
NLOST = NLOST + 1
TP(J) = TLIMIT
GO TO 160
+
0
IRROR = 1960
GO TO 196
CALL ERROR

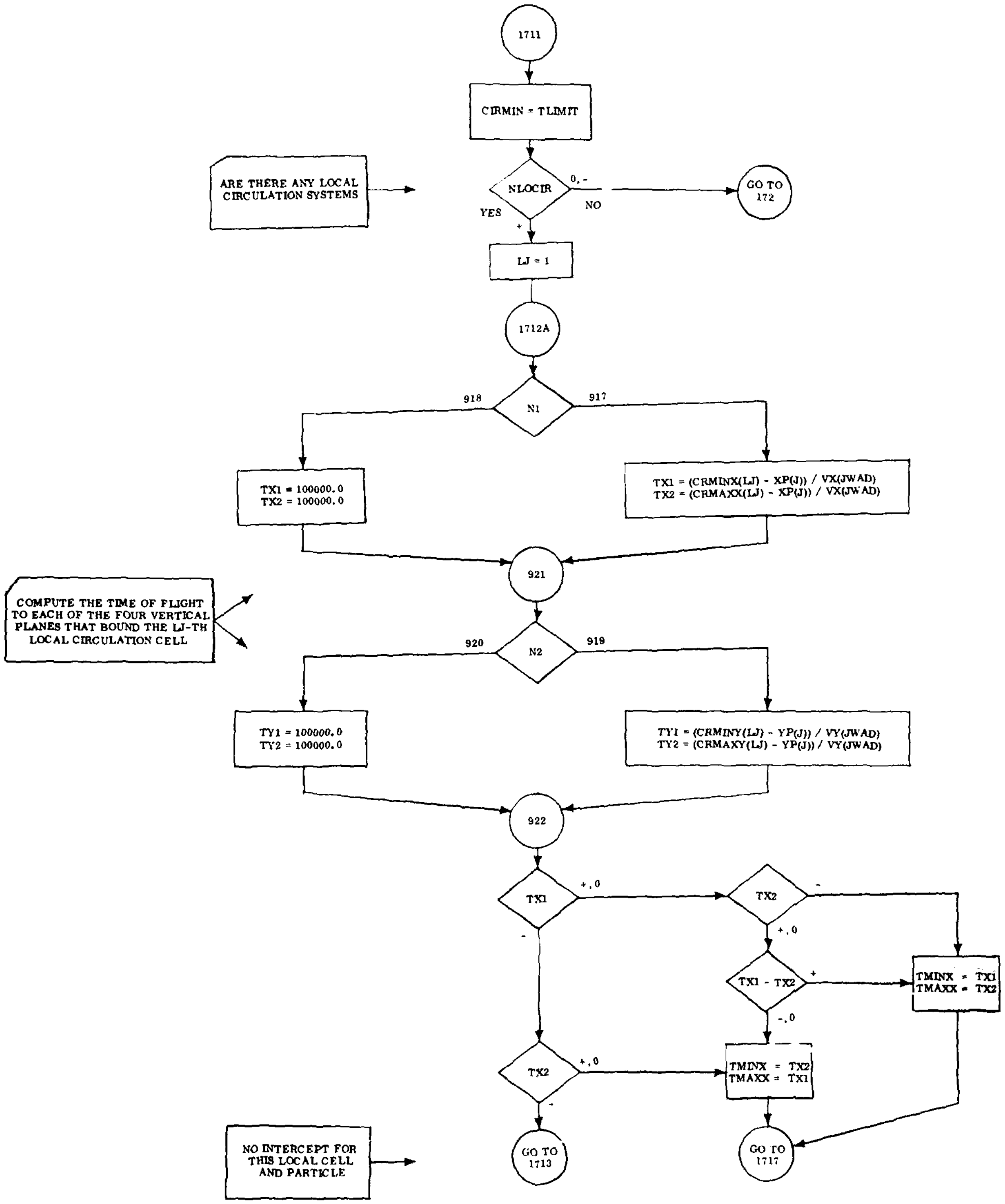
(e)

FC-10. (Continued) Detailed Flow Charts for Subroutine LINK7


196
COMPUTE SETTLING RATE FOR J-TH PARTICLE PUTTING RESULT IN PARAMETER FV
CALL FALRAT
VPZ - VZ(JWAD) - FV
COMPUTE DISTANCES TO THE FOUR NEAREST VERTICAL BOUNDING PLANES OF THE MACRO CELL
XBL = (AINT((XP(J) - WLLX(JW)) / WGRINT(JW))) * WGRINT(JW)
XBU = XBL + WGRINT(JW)
YBL = (AINT((YP(J) - WLLY(JW)) / WGRINT(JW))) * WGRINT(JW)
YBU = YBL + WGRINT(JW)
ASSIGN 917 TO N1
COMPUTE TIME OF FIRST INTERSECTION WITH A NORTH-SOUTH-VERTICAL PLANE
VX(JWAD)
-
0
+
TIX = (XBL - XP(J)) / VX(JWAD)
TIX - 100000. 0
ASSIGN 918 TO N1
TIX - (XBU - XP(J)) / VX(JWAD)
164
ASSIGN 919 TO N2
COMPUTE TIME OF FIRST INTERSECTION WITHIN EAST-WEST-VERTICAL PLANE
VY(JWAD)
-
0
+
TIY = (YBL - YB(J)) / VY(JWAD)
TIY = 100000. 0
ASSIGN 920 TO N2
TIY = (YBU - YP(J)) / VY(JWAD)
168
COMPUTE TIME OF FIRST INTERSECTION WITH A HORIZONTAL PLANE BOUNDARY (STRATUM BOUNDARY OR MAXIMUM TOPOGRAPHIC HEIGHT)
VPZ
-
0
+
ZP(J) - TTOPO
+
-, 0
TIZ = 100000. 0
TIZ = (BOTHIT(JW + 1) - ZP(J)) / VPZ
TTOPO - BOTHIT(JW)
+
-, 0
TIZ = (BOTHIT(JW) - ZP(J)) / VPZ
TIZ = (TTOPO - ZP(J)) / VPZ
GO TO 1711

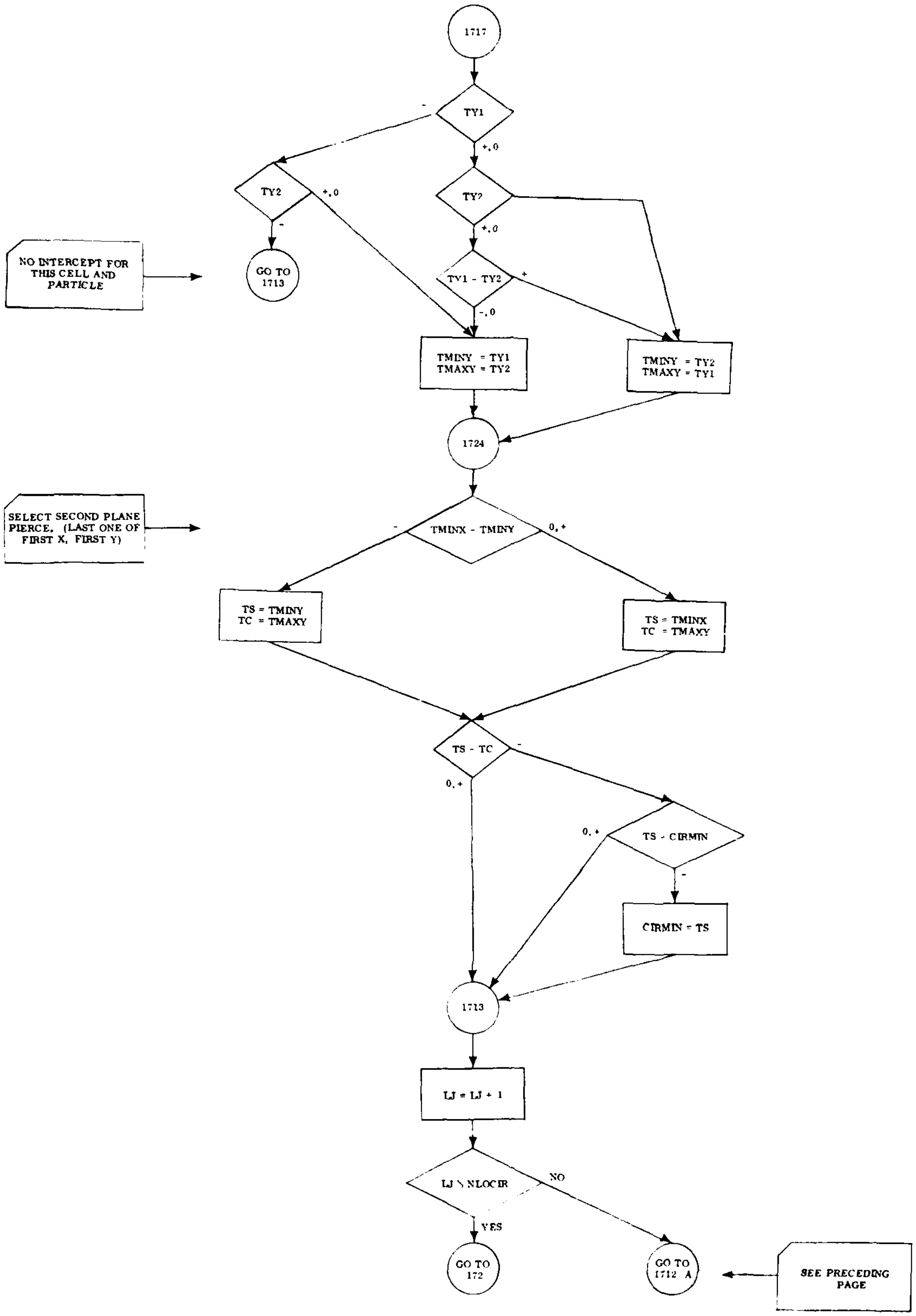
(f)

FC-10. (Continued) Detailed Flow Charts for Subroutine LINK7


1711
CIRMIN = TLIMIT
ARE THERE ANY LOCAL CIRCULATION SYSTEMS
NLOCIR
0, -
NO
GO TO 172
YES
+
LJ = 1
1712A
918
N1
917
TX1 = 100000.0
TX2 = 100000.0
TX1 = (CRMINX(LJ) - XP(J)) / VX(JWAD)
TX2 = (CRMAXX(LJ) - XP(J)) / VX(JWAD)
921
COMPUTE THE TIME OF FLIGHT TO EACH OF THE FOUR VERTICAL PLANES THAT BOUND THE LJ-TH LOCAL CIRCULATION CELL
920
N2
919
TY1 = 100000.0
TY2 = 100000.0
TY1 = (CRMINY(LJ) - YP(J)) / VY(JWAD)
TY2 = (CRMAXY(LJ) - YP(J)) / VY(JWAD)
922
TX1
+, 0
-
TX2
-
+, 0
TX1 - TX2
+
-, 0
TMINX = TX1
TMAXX = TX2
TX2
+, 0
-
TMINX = TX2
TMAXX = TX1
NO INTERCEPT FOR THIS LOCAL CELL AND PARTICLE
GO TO 1713
GO TO 1717

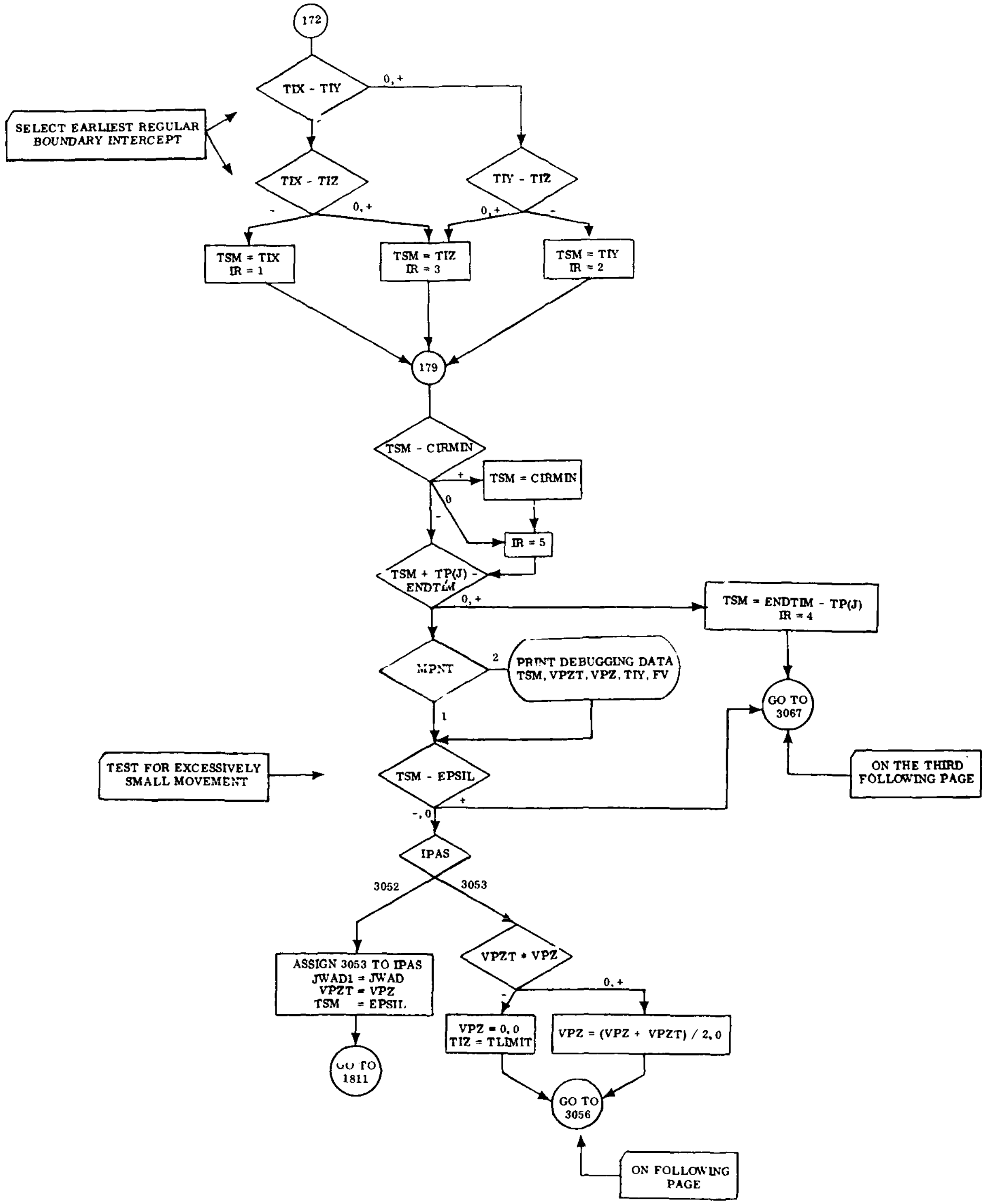
(g)

FC-10. (Continued) Detailed Flow Charts for Subroutine LINK7



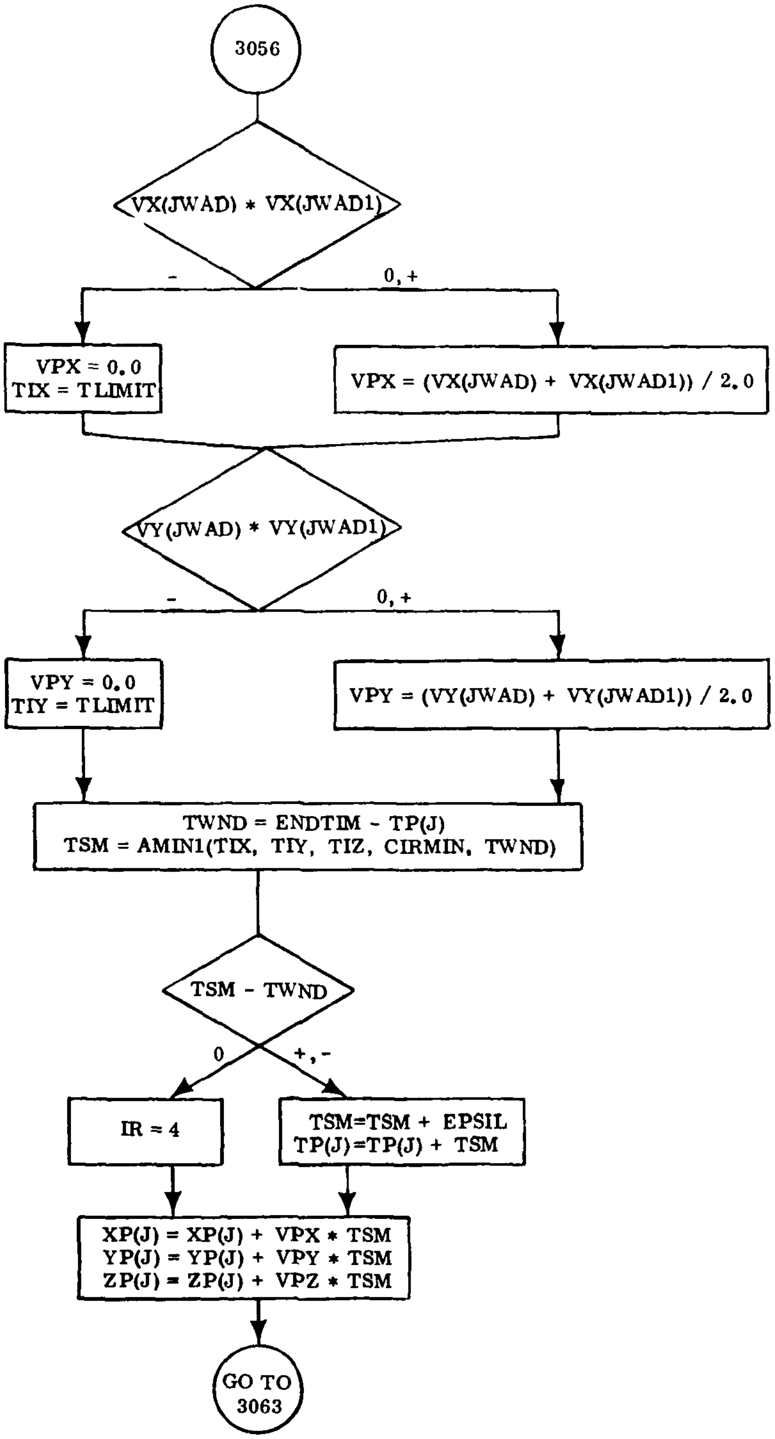
(h)

FC-10. (Continued) Detailed Flow Charts for Subroutine LINK7



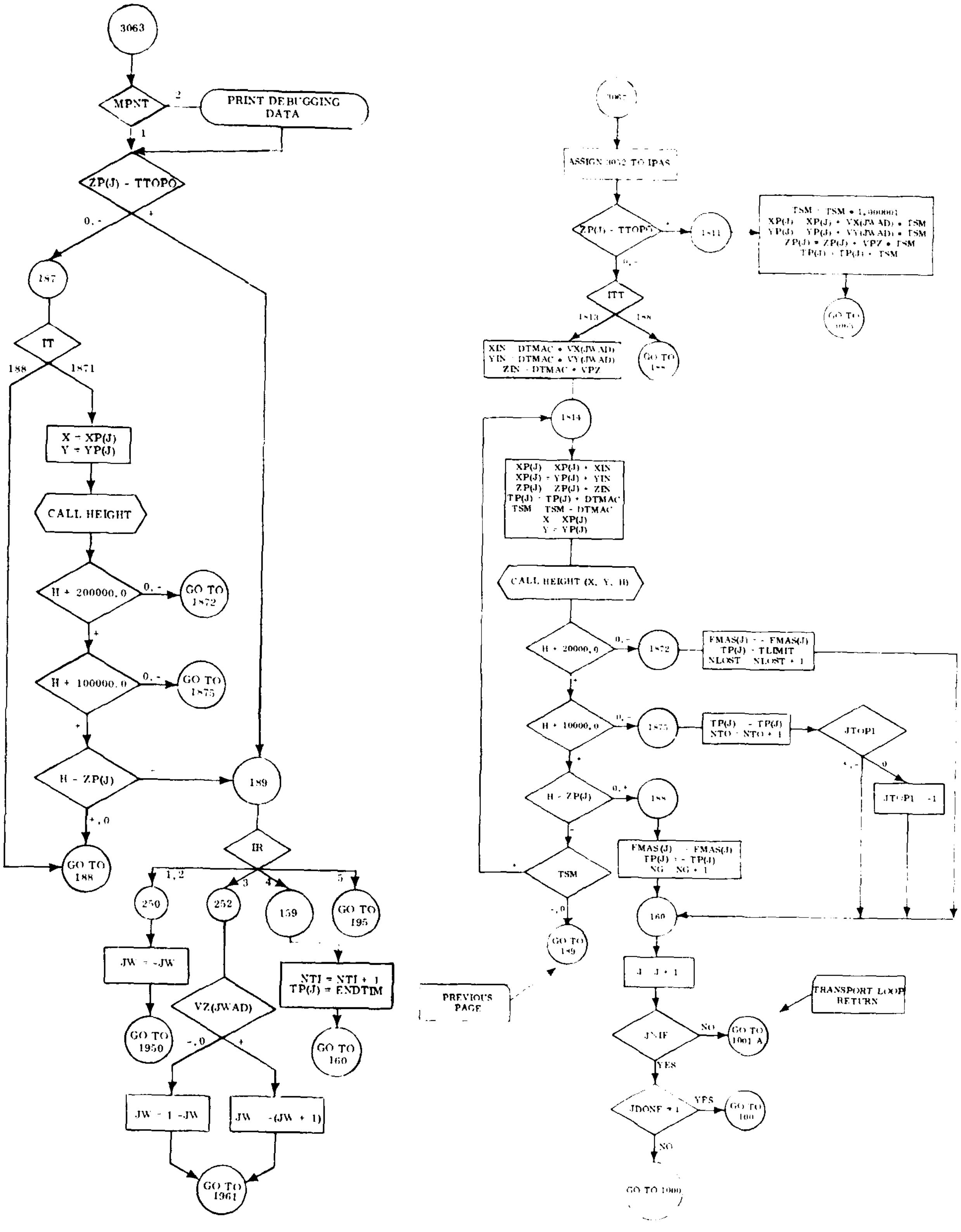
(i)

FC-10. (Continued) Detailed Flow Charts for Subroutine LINK7


3056
VX(JWAD) * VX(JWAD1)
-
0, +
VPX = 0.0
TIX = TLIMIT
VPX = (VX(JWAD) + VX(JWAD1)) / 2.0
VY(JWAD) * VY(JWAD1)
-
0, +
VPY = 0.0
TIY = TLIMIT
VPY = (VY(JWAD) + VY(JWAD1)) / 2.0
TWND = ENDTIM - TP(J)
TSM = AMIN1(TIX, TIY, TIZ, CIRMIN, TWND)
TSM - TWND
0
+, -
IR = 4
TSM=TSM + EPSIL
TP(J)=TP(J) + TSM
XP(J) = XP(J) + VPX * TSM
YP(J) = YP(J) + VPY * TSM
ZP(J) = ZP(J) + VPZ * TSM
GO TO
3063

(j)

FC-10. (Continued) Detailed Flow Charts of Subroutine LINK7



(k)

(l)

FC-10. (Continued) Detailed Flow Charts of Subroutine LINK7

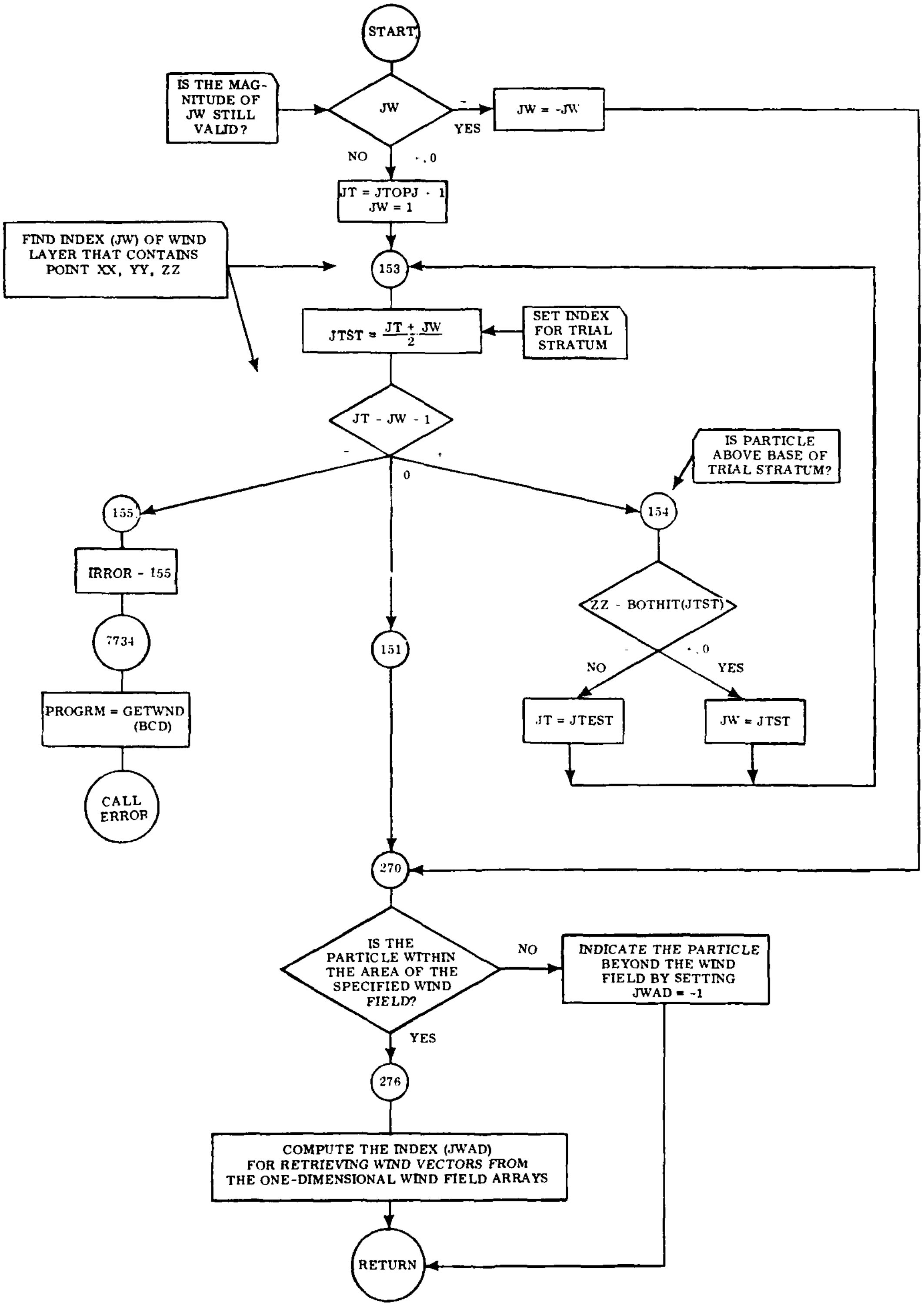
Next, at statement number 270 a check is made to see that the particle is within the bounds of the macrowind field. If it is not, JWAD is set -1 to indicate the problem to the calling program and GETWND returns. If the particle is in a satisfactory position, JWAD is computed to locate the desired vector and then GETWND returns control to the calling program.

Subroutine LOTRAN(J, K) (FC-12)

The purpose of this subroutine is to transport a particle when it is either within or above a local circulation system cell. This program is called from only one place in the main transport program (LINK7). The call is made from within the main transport loop but only when it is known that the particle being transported is either within or above the Kth local circulation cell In the actual execution of LOTRAN, first an assignment is made on the basis of the type (CIRTYP(K)) of circulation program that is applicable within the Kth local cell. The purpose of this assignment is to allow efficient branching to the desired program within the actual local transport loop. After making the assignment the program branches to statement number 120.

At statement 120 the particle settling rate for the current particle is computed and stored in variable FV Then by comparing the particle Z coordinate (ZP(J)) and the height of the top of the Kth local cell we determine whether the particle is above or within the local cell. If the particle is above the cell, we wish to transport the particle making use of the macrowind-field specification. Thus, we call subroutine GETWND to retrieve the macrowind vector for the particle position. Then the vertical particle velocity is computed as the sum of the settling rate, FV, and the vertical wind component. In order to be able to move the particle as far as possible in the next step, we must next compute the time of flight to all applicable boundaries and select the first intercept. These boundaries are an X-boundary plane, a Y-boundary plane, a plane forming a horizontal boundary between layers of the macrowind-field description, and the plane forming the top of the local cell.

Having selected the earliest intercept time, the particle is simply transported for that increment in one step making use of the macrowind vectors. At this point the particle will either be going into the local cell through its top, going out of the


START
IS THE MAGNITUDE OF JW STILL VALID?
JW
-
YES
JW = -JW
NO
+, 0
JT = JTOPJ · 1
JW = 1
FIND INDEX (JW) OF WIND LAYER THAT CONTAINS POINT XX, YY, ZZ
153
JTST = JT + JW / 2
SET INDEX FOR TRIAL STRATUM
JT - JW - 1
-
0
+
IS PARTICLE ABOVE BASE OF TRIAL STRATUM?
155
IRROR - 155
7734
PROGRM = GETWND (BCD)
CALL ERROR
151
154
ZZ - BOTHIT(JTST)
-
+, 0
NO
YES
JT = JTEST
JW = JTST
270
IS THE PARTICLE WITHIN THE AREA OF THE SPECIFIED WIND FIELD?
NO
INDICATE THE PARTICLE BEYOND THE WIND FIELD BY SETTING JWAD = -1
YES
276
COMPUTE THE INDEX (JWAD) FOR RETRIEVING WIND VECTORS FROM THE ONE-DIMENSIONAL WIND FIELD ARRAYS
RETURN

FC-11. Flow Chart for Subroutine GETWND

local transport volume, or resting at a macrowind layer boundary or the time boundary. In any case, a transfer is made to statement number 131.

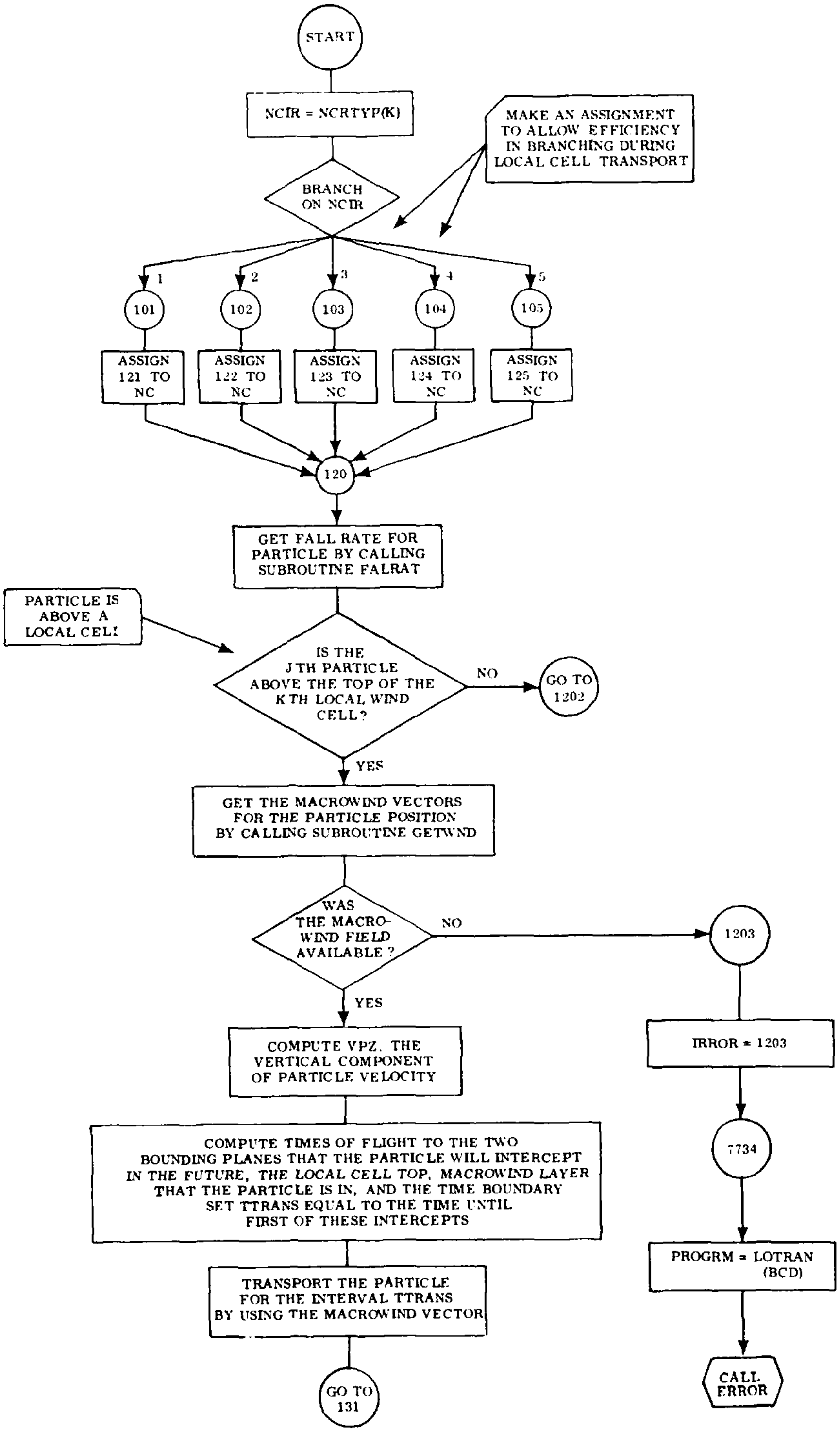
At 131 the program determines whether the particle is still in or above the local cell If it is not, the program is finished and returns. If the particle is still in or above the local cell, the time boundary is checked and if not violated a return is made to the top of the loop at statement 120.

If the particle was originally or is now within the local cell, an ASSIGNED GO TO is used to transfer to a subroutine CALL statement which transfers control to a local circulation system subroutine (either MTWNDI, RGWNDI, or CBREZ1). Within the local circulation system subroutine the three wind velocity vector components are computed at the position of the particle and control then is returned to LOTRAN. The wind vector component is used to transport the particle over one (small) time step by point-slope integration (see p. 37). Particles within the local cell iterate through the transport loop procedure until they either leave the cell or become grounded.

Subroutine MTWND1 (J, K, AX, AY, AZ) (FC-13)

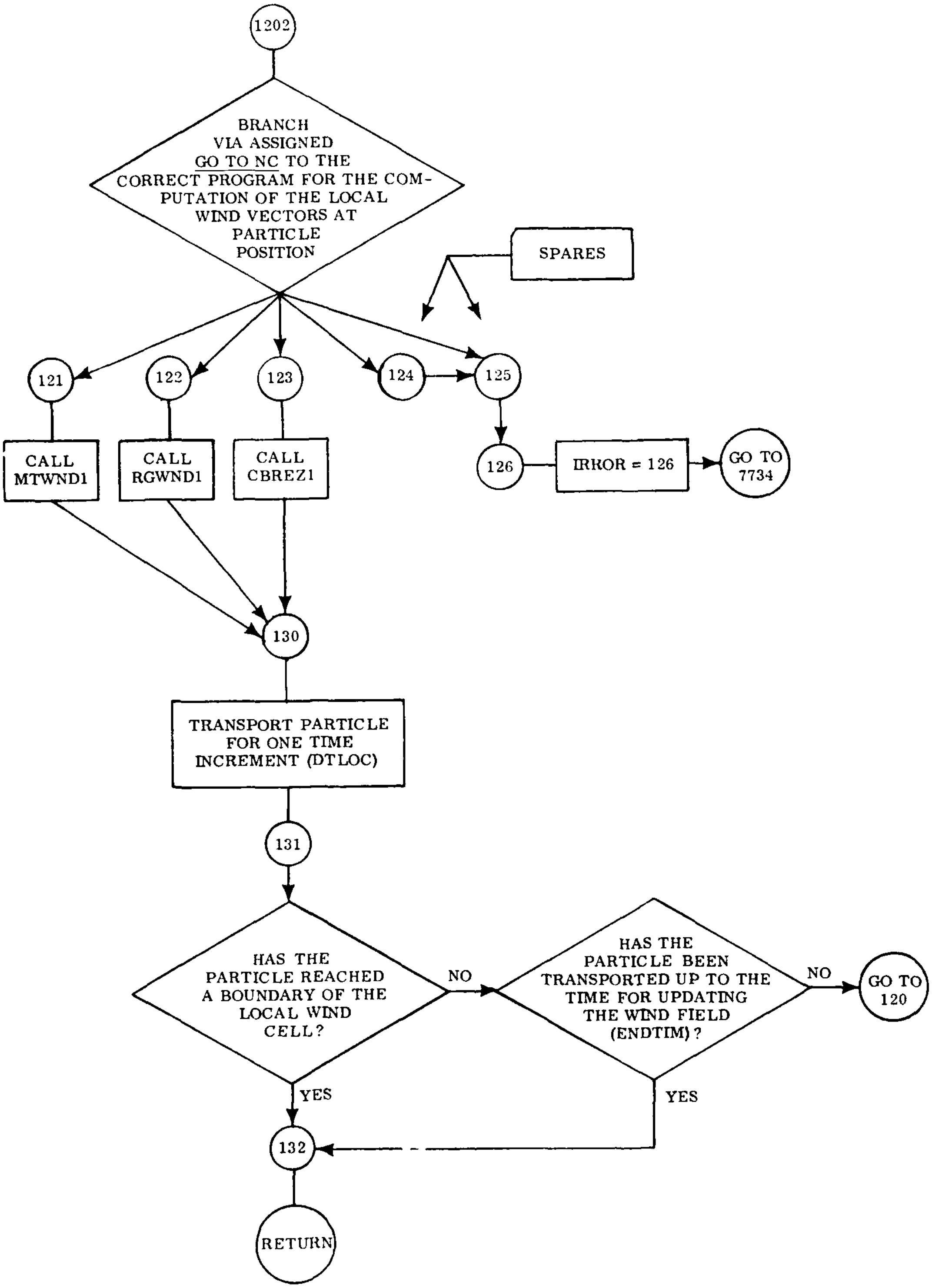
This subroutine, used for the Kth local cell, consists of two logical routes that serve the purpose of (1) reading mountain wind data and (2) computing the mountain wind components for the Jth particle at location XP(J), YP(J), ZP(J) after first checking for impact on the ground. If impact is sensed, the wind velocity is assigned a large downward velocity component, $AZ = -10^8$. The read route, entered when the sign of the argument J is negative, also serves to precompute constant geometrical relationships between the unperturbed wind, mountains, and macrosystem so as to facilitate computation on the compute route. The compute route is entered during actual particle transport when J, now positive, is the argument of the particular particle being moved.

In the read route, first the coordinates XM(I), YM(I), height H(I), and half-width A(I) of the Ith mountain are read for each of the I mountains with I ranging from 1 to NMT, the maximum number of mountains Each mountain is checked for the ratio, H(I)/A(I), and location within the Kth local cell boundaries of north (CRMAXY(K)), south (CRMINY(K)), east (CRMAXX(K)), and west (CRMINX(K)).


START
NCIR = NCRTYP(K)
MAKE AN ASSIGNMENT TO ALLOW EFFICIENCY IN BRANCHING DURING LOCAL CELL TRANSPORT
BRANCH ON NCIR
1
2
3
4
5
101
102
103
104
105
ASSIGN 121 TO NC
ASSIGN 122 TO NC
ASSIGN 123 TO NC
ASSIGN 124 TO NC
ASSIGN 125 TO NC
120
GET FALL RATE FOR PARTICLE BY CALLING SUBROUTINE FALRAT
PARTICLE IS ABOVE A LOCAL CELL
IS THE JTH PARTICLE ABOVE THE TOP OF THE KTH LOCAL WIND CELL?
NO
GO TO 1202
YES
GET THE MACROWIND VECTORS FOR THE PARTICLE POSITION BY CALLING SUBROUTINE GETWND
WAS THE MACRO-WIND FIELD AVAILABLE ?
NO
1203
YES
COMPUTE VPZ, THE VERTICAL COMPONENT OF PARTICLE VELOCITY
IRROR = 1203
COMPUTE TIMES OF FLIGHT TO THE TWO BOUNDING PLANES THAT THE PARTICLE WILL INTERCEPT IN THE FUTURE, THE LOCAL CELL TOP, MACROWIND LAYER THAT THE PARTICLE IS IN, AND THE TIME BOUNDARY SET TTRANS EQUAL TO THE TIME UNTIL FIRST OF THESE INTERCEPTS
7734
PROGRM = LOTRAN (BCD)
TRANSPORT THE PARTICLE FOR THE INTERVAL TTRANS BY USING THE MACROWIND VECTOR
CALL ERROR
GO TO 131

(a)

FC-12. Flow Charts for Subroutine LOTRAN


1202
BRANCH VIA ASSIGNED GO TO NC TO THE CORRECT PROGRAM FOR THE COMPUTATION OF THE LOCAL WIND VECTORS AT PARTICLE POSITION
SPARES
121
122
123
124
125
CALL MTWND1
CALL RGWND1
CALL CBREZ1
126
IRROR = 126
GO TO 7734
130
TRANSPORT PARTICLE FOR ONE TIME INCREMENT (DTLOC)
131
HAS THE PARTICLE REACHED A BOUNDARY OF THE LOCAL WIND CELL?
NO
HAS THE PARTICLE BEEN TRANSPORTED UP TO THE TIME FOR UPDATING THE WIND FIELD (ENDTIM)?
NO
GO TO 120
YES
YES
132
RETURN

(b)

FC-12. (Continued) Flow Charts for Subroutine LOTRAN

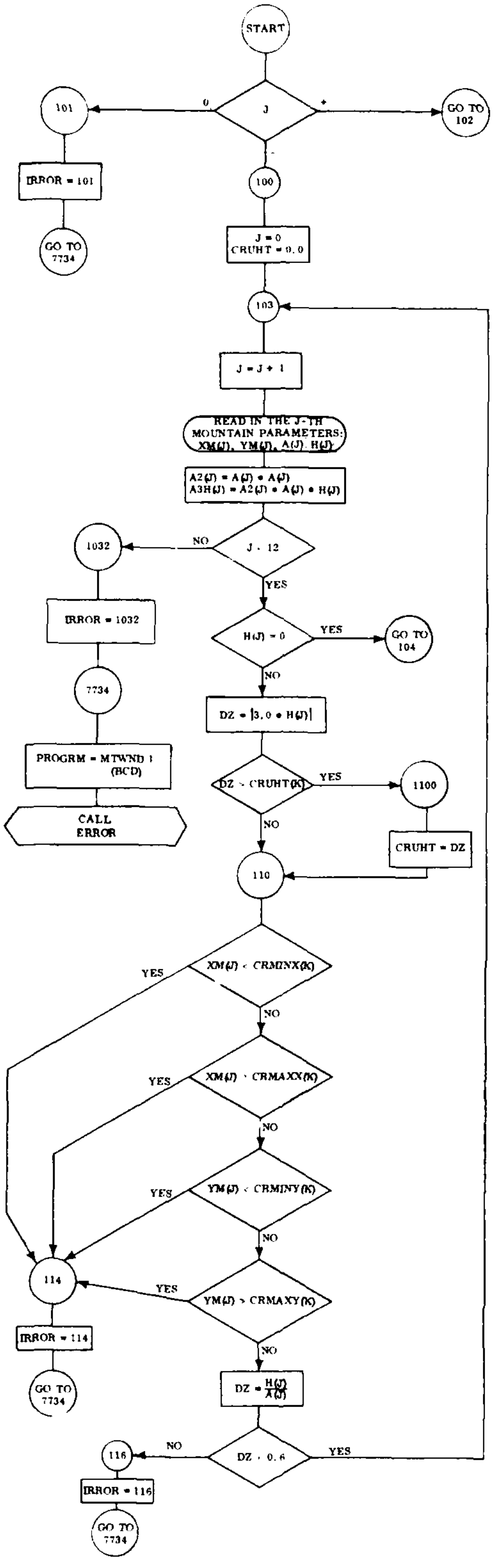
The height CRUHT(K), of the Kth cell is defined as three times the height of the tallest mountain. The error subroutine is called if a mountain ratio exceeds 0.6, if a mountain does not lie within the boundaries of the Kth local cell, or if the number of mountains exceeds the maximum of twelve mountains allowed in the Kth cell.

Next the read route computes the geometric center, (XX, YY, ZZ) of the Kth local cell and calls the subroutine GETWND to retrieve the index JWAD of the unperturbed wind vector at that (XX, YY, ZZ) location within the macrowind field. A nonpositive JWAD index will call the ERROR subroutine. Using the stored wind components indexed on JWAD, the magnitude of the unperturbed wind vector, UO(K) and its direction in the macrowind field are computed. Constant parameters used in the compute route are also computed and stored. The local cell identification, the mountains, the unperturbed wind vector, and the boundaries of the local cell are printed out. This ends the read route.

The computing route first determines the distance of the Jth particle from the Ith mountain in terms of a component parallel and a component perpendicular to the direction of the unperturbed wind. The analytical height of the Ith mountain at this particle location is also determined. Then, the perturbed wind components parallel, horizontally perpendicular, and vertically perpendicular to the unperturbed wind vector are calculated. The height and perturbed wind components due to each mountain are summed, and DZ, the total analytic height of the mountain, is checked against ZP(J), the height of the particle, to determine impact. If DZ is greater than ZP(J), the velocity (0, 0, -10^8) is assigned to the wind. However, if the particle is still aloft, the unperturbed wind vector is added to the summed perturbed components, the resulting influence of all the mountains, and the wind-field vector is rotated back into the macrowind-field coordinate system. This ends the compute route with the desired wind components stored in variables AX, AY, and AZ.

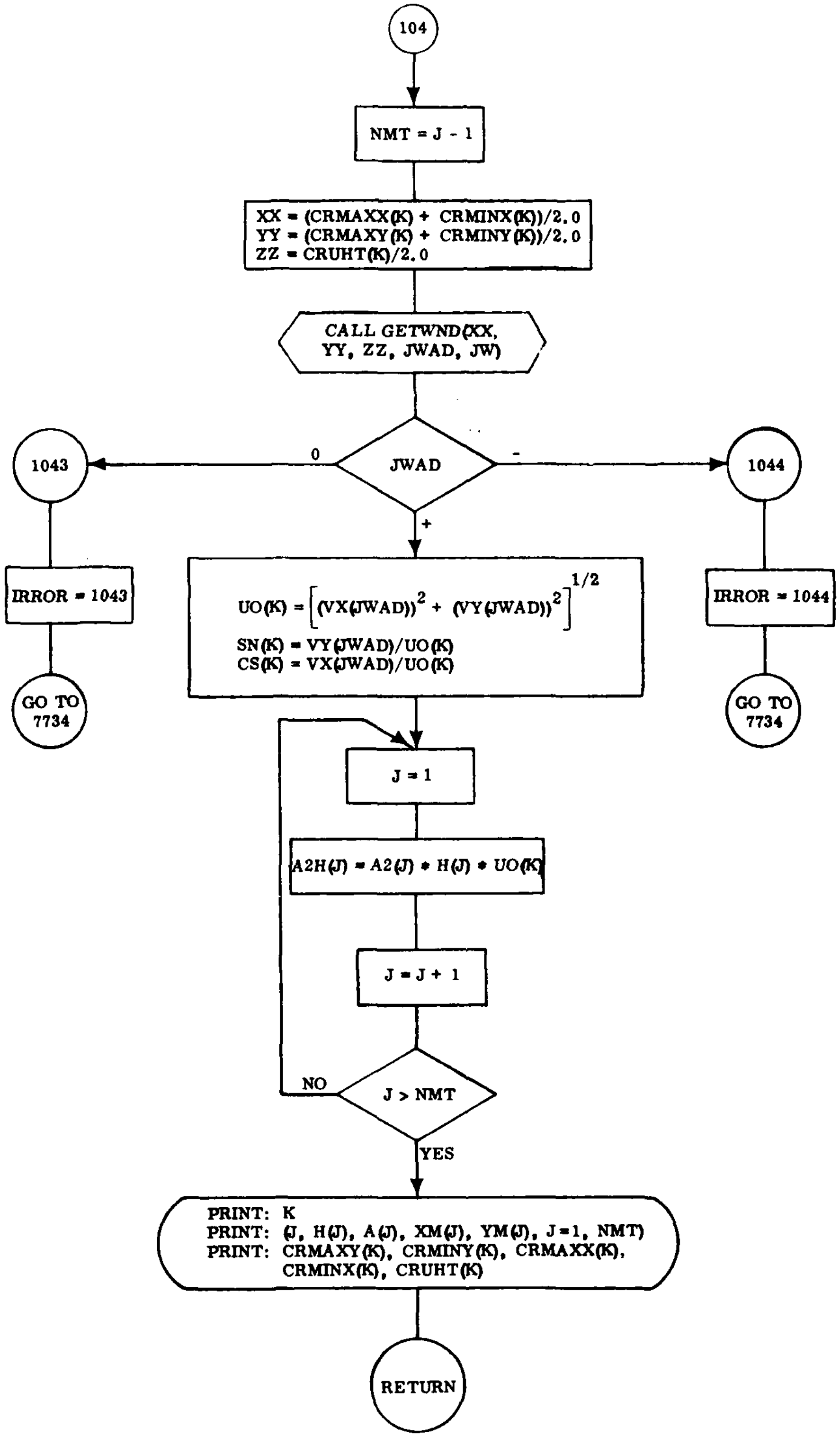
<u>Subroutine RGWND1(J, K, AX, AY, AZ) (FC-14)</u>

This subroutine for the Kth local cell consists of two logical routes that serve the purpose of reading ridge wind data and computing the ridge wind components for the Jth particle at location XP(J), YP(J), ZP(J) after first checking for impact on



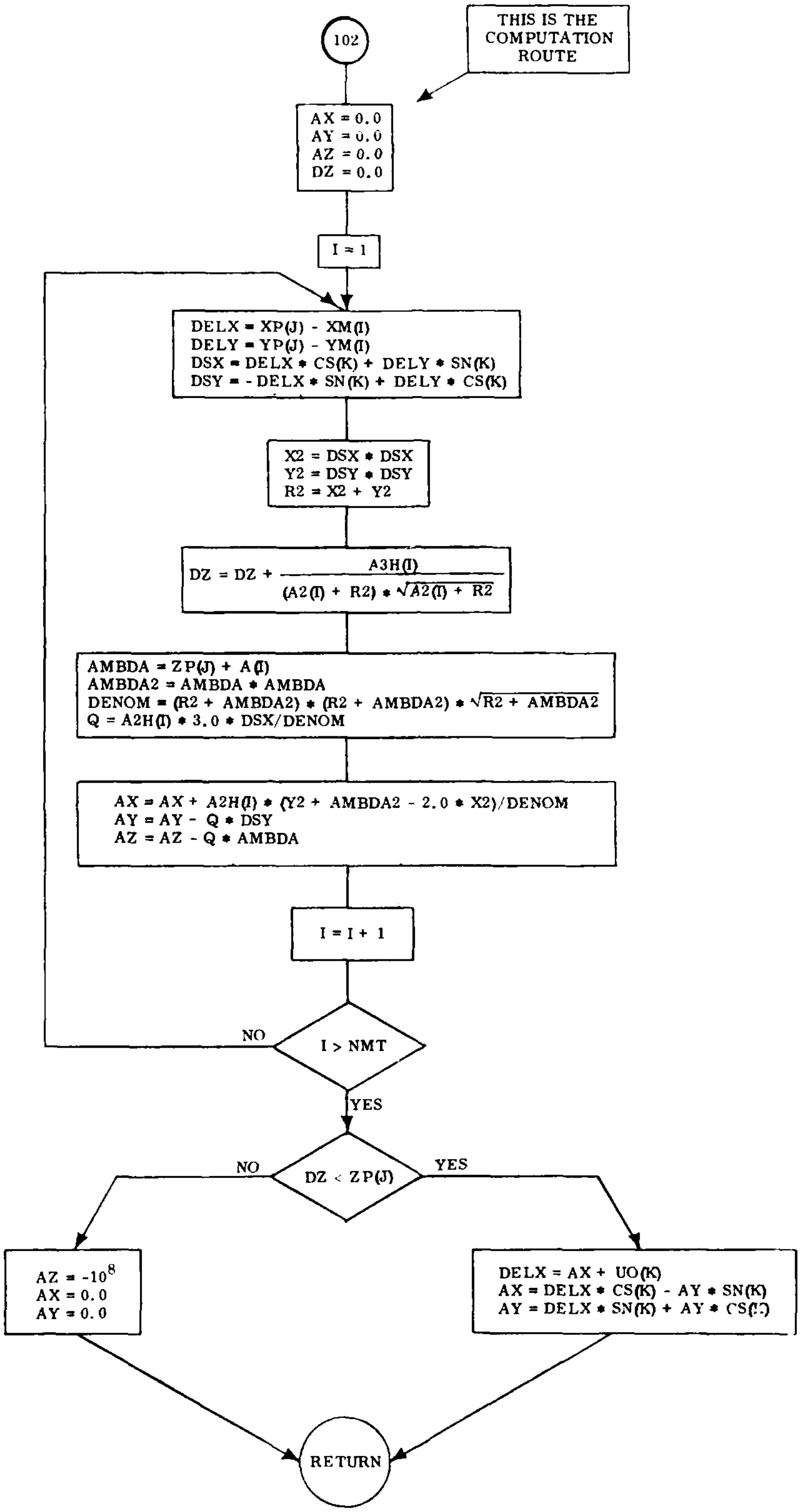
(a)

FC-13. Flow Charts for Subroutine MTWND1


104
NMT = J - 1
XX = (CRMAXX(K) + CRMINX(K))/2.0
YY = (CRMAXY(K) + CRMINY(K))/2.0
ZZ = CRUHT(K)/2.0
CALL GETWND(XX, YY, ZZ, JWAD, JW)
JWAD
0
-
+
1043
1044
IRROR = 1043
IRROR = 1044
GO TO 7734
GO TO 7734
UO(K) = [(VX(JWAD))^2 + (VY(JWAD))^2]^1/2
SN(K) = VY(JWAD)/UO(K)
CS(K) = VX(JWAD)/UO(K)
J = 1
A2H(J) = A2(J) * H(J) * UO(K)
J = J + 1
J > NMT
NO
YES
PRINT: K
PRINT: (J, H(J), A(J), XM(J), YM(J), J=1, NMT)
PRINT: CRMAXY(K), CRMINY(K), CRMAXX(K), CRMINX(K), CRUHT(K)
RETURN

(b)

FC-13. (Continued) Flow Charts for Subroutine MTWND1


102
THIS IS THE COMPUTATION ROUTE
AX = 0.0
AY = 0.0
AZ = 0.0
DZ = 0.0
I = 1
DELX = XP(J) - XM(I)
DELY = YP(J) - YM(I)
DSX = DELX * CS(K) + DELY * SN(K)
DSY = - DELX * SN(K) + DELY * CS(K)
X2 = DSX * DSX
Y2 = DSY * DSY
R2 = X2 + Y2
DZ = DZ + A3H(I) / (A2(I) + R2) * √A2(I) + R2
AMBDA = ZP(J) + A(I)
AMBDA2 = AMBDA * AMBDA
DENOM = (R2 + AMBDA2) * (R2 + AMBDA2) * √R2 + AMBDA2
Q = A2H(I) * 3.0 * DSX/DENOM
AX = AX + A2H(I) * (Y2 + AMBDA2 - 2.0 * X2)/DENOM
AY = AY - Q * DSY
AZ = AZ - Q * AMBDA
I = I + 1
NO
I > NMT
YES
NO
DZ < ZP(J)
YES
AZ = -10^8
AX = 0.0
AY = 0.0
DELX = AX + UO(K)
AX = DELX * CS(K) - AY * SN(K)
AY = DELX * SN(K) + AY * CS(K)
RETURN

(c)

FC-13. (Continued) Flow Charts for Subroutine MTWND1 the ground. If impact is sensed, the wind velocity is assigned a large downward velocity component. The read route, entered when the sign of argument J is minus, serves to pre-compute constant geometrical relationships between the ridges, unperturbed wind, and macrosystem to facilitate computation during the compute route. The compute route is entered during actual particle transport when J, now positive, is the argument of the particular particle being moved.

In the read route, first the coordinates XM(I), YM(I), height H(I), halfwidth A(I), and orientation B(I) of the Ith ridge are read for I ranging from 1 to NRG, the maximum number of ridges. The orientation, B(I), of a ridge is defined as the clockwise rotation of the ridge in radians, where zero radians indicates a ridge oriented north-south. Each ridge is checked for the ridge ratio, H(I)/A(I), and for location within the Kth local cell boundaries of north (CRMAXY(K)), south (CRMINY(K)), east (CRMAXX(K)) and west (CRMINX(K)). The height, CRUHT(K), of the Kth cell is defined as three times the height of the tallest ridge. The error subroutine is called if: a ridge ratio exceeds 0. 6, a ridge does not lie within the boundaries of the Kth cell, or the number of ridges exceeds the maximum of twelve ridges allowed in the Kth cell.

Next, the read route computes the geometric center (XX, YY, ZZ) of the Kth local cell and calls the subroutine GETWND to retrieve JWAD, the index of the unperturbed wind vector at that (XX, YY, ZZ) location within the macrowind field. A nonpositive JWAD index will lead to the ERROR subroutine. Using the stored wind components indexed on JWAD, the magnitude of the unperturbed wind vector, UO(K), and its direction in the macrowind field are computed. Constant geometrical relationships between wind vector components (UO(K)), the macrowind field, and the orientation and location of the ridges are computed and stored for use in the compute route. The local cell identification, the ridges, the retrieved unperturbed wind vector, and the boundaries of the local cell are printed out. This ends the read route.

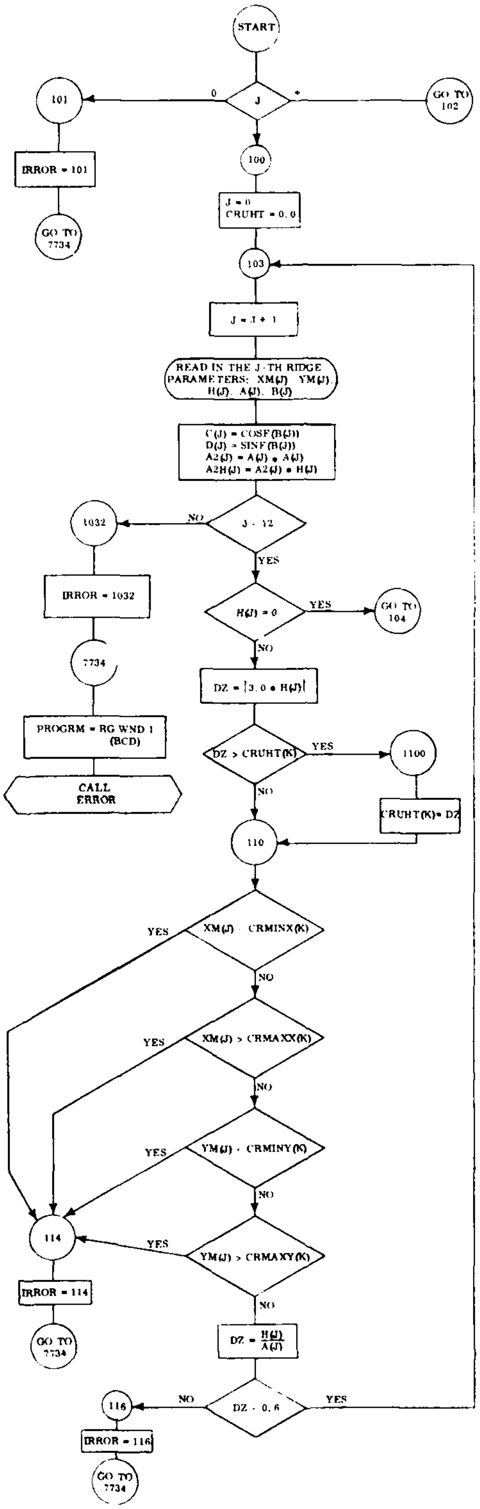
The computing route first determines the perpendicular distance of the Jth particle from the Ith ridge. The analytical height of the ground and the parallel, horizontally perpendicular, and vertically perpendicular perturbed wind components with respect to the unperturbed wind, UO(K), are now computed at this particle position. The results for each ridge are summed with the succeeding ridges to yield total height and perturbed wind vectors due to all the ridges at this point. Next, the particle height, ZP(J), is checked against the total analytical ground height, DZ, to determine impact; upon which, the velocity $(0, 0, -10^8)$ msec^{-1} is assigned to the wind. However, if the particle is still aloft, the unperturbed wind vector is added to the summed perturbed components and the result is rotated back into the macrowind field coordinate system. This ends the compute route with the desired wind components stored in variables AX, AY, and AZ.

Subroutine CBREZ1(J, K, AX, AY, AZ) (FC-15)

Before attempting to use the sea-breeze local circulation system, the reader is advised to obtain a thorough understanding of the model by studying the presentations in the Physical and Mathematical Models section and in Appendix B.

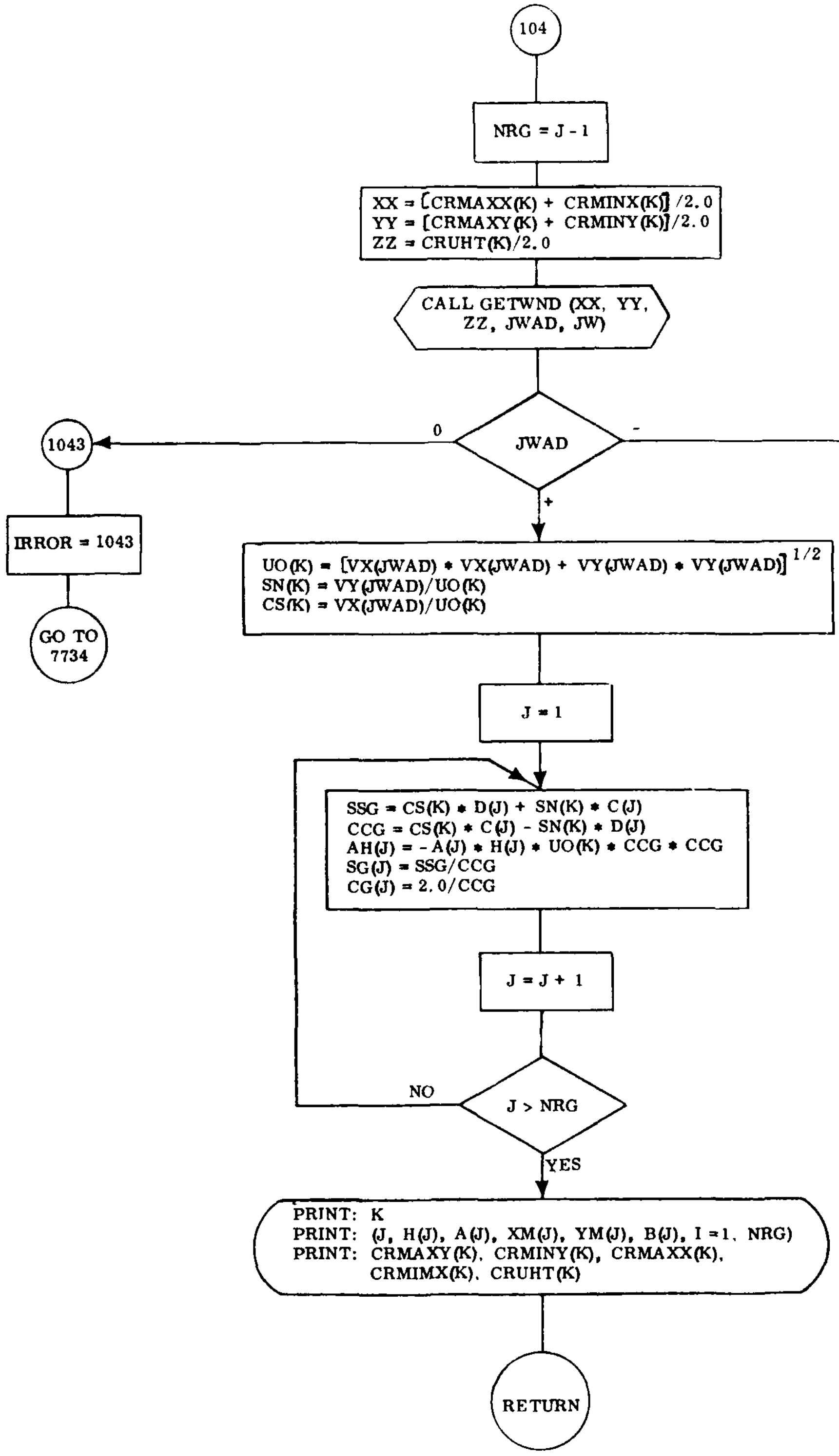
The CBREZ1 subroutine serves the dual purpose of reading the sea-breeze data and computing the sea-breeze velocity components for the Jth particle at location XP(J), YP(J), ZP(J) and time TP(J), after first checking for particle impact at sea level. The programming of CBREZ1 is divided into two mutually exclusive chains of logic that will be referred to as the read route and the compute route. The read route, entered at statement number 100 when the sign of the argument J is negative, also serves to pre-compute constant sea breeze parameters to facilitate computation during the compute route. The compute route is entered during actual particle transport when J, now positive, is the index of the particular particle being moved.

The read route starts by reading from the system input tape values for parameters B, GRAD, NN and the pairs DELTX(N) and TAUX(N) for N ranging from 1 to NN. The maximum value of NN is nine (see Table 3). N represents the order of the harmonic described by DELTX(N) and TAUX(N). These parameters serve to calculate OMGX(N), AJZX(N), AJXX(N), AJY(N), R1RX(N), R1IX(N), R2RX(N), R2IX(N), ESQ1, ESQ2, AN1, AN2, FAX(N), T1, DELTX(N), and TAUX(N), for each Nth harmonic, and are printed out as the respective symbols: OMGN(N), AJZ(N), AJX(N), AJY(N), AKN1(N), ALN1(N), AKN2(N), ALN2(N), BLOW1(N), BLOW2(N),



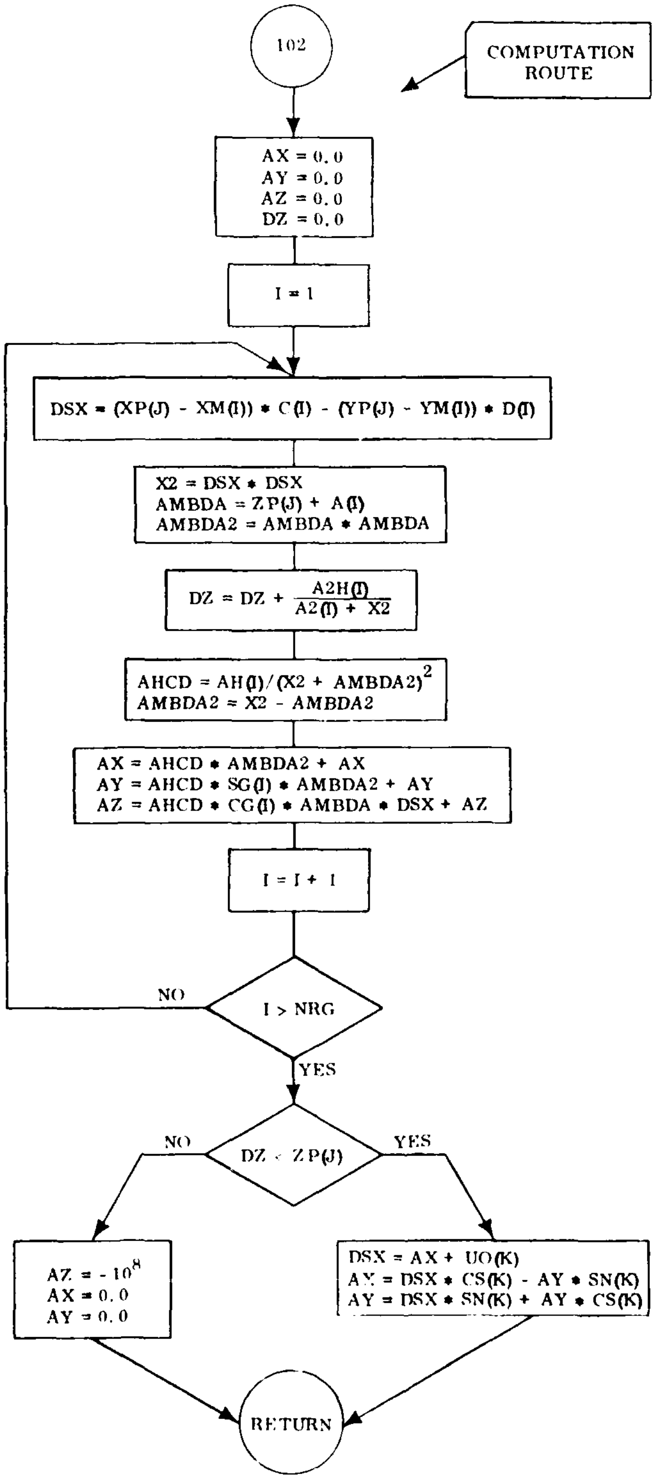
(a)

FC-14. Flow Charts for Subroutine RGWND1


104
NRG = J - 1
XX = [CRMAXX(K) + CRMINX(K)] /2.0
YY = [CRMAXY(K) + CRMINY(K)]/2.0
ZZ = CRUHT(K)/2.0
CALL GETWND (XX, YY, ZZ, JWAD, JW)
JWAD
0
-
+
1043
IRROR = 1043
GO TO 7734
1044
IRROR = 1044
GO TO 7734
UO(K) = [VX(JWAD) * VX(JWAD) + VY(JWAD) * VY(JWAD)] 1/2
SN(K) = VY(JWAD)/UO(K)
CS(K) = VX(JWAD)/UO(K)
J = 1
SSG = CS(K) * D(J) + SN(K) * C(J)
CCG = CS(K) * C(J) - SN(K) * D(J)
AH(J) = - A(J) * H(J) * UO(K) * CCG * CCG
SG(J) = SSG/CCG
CG(J) = 2.0/CCG
J = J + 1
J > NRG
NO
YES
PRINT: K
PRINT: (J, H(J), A(J), XM(J), YM(J), B(J), I = 1, NRG)
PRINT: CRMAXY(K), CRMINY(K), CRMAXX(K),
CRMIMX(K), CRUHT(K)
RETURN

(b)

FC-14. (Continued) Flow Charts for Subroutine RGWND1



(c)

FC-14. (Contined) Flow Charts for Subroutine RGWND1

ANN1(N), ANN2(N), PHIN(N), ENU(N), DELTX(N), and TAUX(N). Correspondences of these mnemonics with the symbols defined in the Physical and Mathematical Models section are given in Tables 3 and 4.

During the computation of these constants checks are made to ensure that SGMA, the Guldberg-Mohn friction parameter, and AKY, the thermal eddy diffusivity, are not zero. If either one of these constants is zero, subroutine ERROR is called.

Also calculated in the read route are the height, CRUHT(K), of the sea-breeze cell and geometrical constants to rotate the particle coordinates and wind vectors in and out of the sea-breeze system. The angle of rotation, B, is zero when the sea lies on the west side of a shore line parallel to the north-south axis. The shore line is defined to run through the center, (XCB, YCB), of the area bounded by the north (CRMAXY(K)), south (CRMINY(K)), east (CRMAXX(K)), and west (CRMINX(K)) vertical sides of the sea-breeze cell. The printout from the read route sequentially consists of the local cell identification, the cell boundaries, the input parameters, and the harmonic parameters.

The compute route first checks particle altitude, ZP(J), against sea level. It assigns the wind vector (0, 0, -10^8) for negative altitudes and returns to the calling program. The coordinates of the particles nonnegative altitude are rotated into the sea-breeze coordinate system. If the horizontal distance between the particle and the shore line (measured perpendicular to the shore line) is greater than the half width of the sea-breeze cell, an exponential attenuation based on the perpendicular distance from the edge of this primary cell is used. No attenuation is used within the primary cell.

The wind-field constants for each harmonic mode are now calculated. The vertical (AZ) and the horizontally parallel (AY) and perpendicular (AZ)(with respect to the shore line) wind vectors are computed from Eqs. (60), (61), and (62) and summed over all the harmonic modes. The resultant wind vectors are next rotated back into macrowind-field coordinates and subroutine CBREZ1 returns control to the calling program.

To aid the user in evaluating the properties of the sea-breeze circulation system generated from the input data, an "interpretative output" of key model parameters is provided. This output is described in Table 4. These parameters are

TABLE 3

INPUT QUANTITIES FOR THE SEA BREEZE

Physical Quantity	Text Designation	Program Designation	Dimension Units	Typical Values and Comments
Number of harmonics	n	NN		Approximately two or three
Total extent of sea breeze	L_x	ELX	m	Less than 10^5m
Sine of latitude	$\sin \phi$	SNPHI		$-1 \leq \sin \phi \leq + 1$
Angle of coastline relative to y axis of grid	ψ	B		
Wind field extrapolation attenuation constant	k_a	WW	m^{-1}	$0 \leq k_a \leq \infty$
Guldberg-Mohn friction parameter	σ	SGMA	sec^{-1}	A value of zero is not allowed; typical values $0.5 \times 10^{-4} \leq \sigma \leq 2.5 \times 10^{-4}$
Average ground temperature	θ_o	THET	^oK	Expressed in degrees Kelvin: $\theta_o = 300^oK$
Unperturbed temperature gradient	$\Gamma = (d\theta_o/dz)$	GRAD	$^oKm^{-1}$	A constant z-independent positive value must be used; typical values $2 \times 10^{-3} \leq \Gamma \leq 7.5 \times 10^{-3}$
Thermal eddy diffusivity	K	AKY	$m^2 sec^{-1}$	A constant z-independent value must be used; typical values $25 \leq K \leq 75$
Magnitude of nth temperature differential	T_n^*	DELTX(N)	^oK	First harmonic will generally be less than 10^oK, with subsequent harmonics decreasing in magnitude
Phase of nth temperature differential	τ_n	TAUX(N)		Phase of first harmonic should correspond to about 1 hr, or $\tau_1 \sim \Omega (3.6) \times 10^3 = 0.26$
Lag time between sea-breeze local time and Greenwich time	Δt_s	ELAG	sec	

TABLE 4

INTERPRETATIVE OUTPUT DESCRIPTION

Output Designation	Text Designation	Interpretative Output Description Designation
OMGN(N)	$n\Omega$	$n\Omega$
AJZ (N)	J_{nz}	$-T_n^* L/B$
AJX(N)	J_{nx}	$\lambda^{-1} J_{nz}$
AJY(N)	J_{ny}	$G J_{nx}$
AKN1(N)	k_{n1}	k_1
ALN1(N)	ℓ_{n1}	ℓ_1
AKN2(N)	k_{n2}	k_2
ALN2(N)	ℓ_{n2}	ℓ_2
BLOW1(N)	$\overline{K}_{n1}$	$\epsilon_1 U_1$
BLOW2(N)	$\overline{K}_{n2}$	$\epsilon_2 U_2$
ANN1(N)	η_{n1}	η_1
ANN2(N)	η_{n2}	η_2
PHIN(N)	ϕ_n	$h - m + \tau_n$
ENU(N)	ν_n	$-\theta_1$

are sufficient to calculate the wind velocity components w_n, u_n, and v_n as given by Eqs. (60), (61), and (62). Column 1 of Table 4 gives the parameter designation in the computer output and column 2 gives the parameter designations in the text. In order that the user may be able to understand in detail the computations required for evaluation of these parameters, a path through the calculation is presented in the paragraphs to follow. Column 3 of Table 4 gives the expressions, in terms of the fundamental quantities used in the following calculation description, used to calculate the parameters in column 2.

After reading the input data, the machine computes the constants:

$$f = 2\Omega \sin \phi \quad ,$$

$$\lambda = (2\pi/L_x) \quad ,$$

$$\alpha = g/\theta_o \quad .$$

At this point the selection of the harmonic mode takes place. Since all the physical quantities with the exception of the input parameters T_n^* and τ_n depend on the mode only through their dependence on $n\Omega$, we now set

$$\Omega = n\Omega \quad .$$

When the foregoing substitution is made it becomes possible to drop the subscript n, it being understood that we are dealing with the nth mode. This permits many of the dummy analytical variables subsequently defined to bear a one-to-one correspondence with the mode-dependent variables. For instance, defined quantities such as q, a, b, and ϵ_1 correspond to q_n, a_n, b_n, ϵ_{1n}.

The next group of calculations is:

$$q = \sigma + i\Omega = A_1 e^{i\theta_1}, \; A_1 = \left(\sigma^2 + \Omega^2\right)^{1/2}, \; \theta_1 = \tan^{-1} (\Omega/\sigma) \; ;$$

$$q^2 = A_2 e^{i\theta_2}, \; A_2 = A_1^2 , \; \theta_2 = 2\theta_1 \; ;$$

$$q^2 + f^2 = A_3 e^{i\theta_3}, \; A_3 = \left(\left(\sigma^2 + f^2 - \Omega^2\right)^2 + 4\Omega^2\sigma^2\right)^{1/2}, \; \theta_3 = \tan^{-1}\left(\frac{2\Omega\sigma}{\sigma^2 + f^2 - \Omega^2}\right) .$$

We next turn our attention to the coefficients a, b, c and d:

$$a = q^2\lambda^2 / \left(q^2+f^2\right) = A_4 e^{i\theta_4},\ A_4 = \left(A_2\lambda^2/A_3\right),\ \theta_4 = \theta_2 - \theta_3 \quad ;$$

$$b = q\alpha\lambda^2 / \left(q^2+f^2\right) = Le^{ih},\ L = \left(A_1\alpha\lambda^2/A_3\right),\ h = \theta_1 - \theta_3 \quad ;$$

$$c = (\Gamma/K) = A_7 \ ;$$

$$d = i\,(\Omega/K) = iA_6,\ A_6 = (\Omega/K)\ .$$

At this point the roots of the dispersion relationship are calculated. First we have:

$$\mu_1 = \frac{a+d}{2} + \frac{R}{2} = C_1 + iD_1 = E_1 e^{i\gamma_1} \quad ,$$

$$\mu_2 = \frac{a+d}{2} - \frac{R}{2} = C_2 + iD_2 = E_2 e^{i\gamma_2} \quad ,$$

$$R = \left((a+d)^2 - 4\,(ad+bc)\right)^{1/2} = Be^{im} \quad ,$$

where

$$(a+d) = A_4\cos\theta_4 + i\left(A_4\sin\theta_4 + A_6\right)$$

$$= \xi_1 + i\,\xi_2 \ ,$$

$$(a+d)^2 - 4(ad+bc) = B_1 + i\,B_2 = \left(B_1^2 + B_2\right)^{1/2} e^{i\beta} \ ,$$

and

$$B_1 = \xi_1^2 - \xi_2^2 - 4\left(LA_7 \cos h - A_4A_6 \sin\theta_4\right) \ ,$$

$$B_2 = 2\,\xi_1\,\xi_2 - 4\left(A_4A_6 \cos\theta_4 + LA_7 \sin h\right) \ ,$$

$$\beta = \tan^{-1}\left(B_2/B_1\right) .$$

We define

$$B = \left(B_1^2 + B_2^2\right)^{1/4} ,$$

$$m = \beta/2 .$$

Using the foregoing expressions, C_1, D_1, C_2, D_2, E_1, E_2, γ_1, and γ_2 are then calculated.

$$C_1 = \frac{1}{2}\left[A_4 \cos\theta_4 + B\cos m\right] ; D_1 = \frac{1}{2}\left[A_4 \sin\theta_4 + A_6 + B\sin m\right] ;$$

$$C_2 = \frac{1}{2}\left[A_4 \cos\theta_4 - B\cos m\right] ; D_2 = \frac{1}{2}\left[A_4 \sin\theta_4 + A_6 - B\sin m\right] ;$$

$$\gamma_1 = \tan^{-1}\left(D_1/C_1\right) ; \gamma_2 = \tan^{-1}\left(D_2/C_2\right) ;$$

$$E_1 = \left(C_1^2 + D_1^2\right)^{1/2} ; E_2 = \left(C_2^2 + D_2^2\right)^{1/2} .$$

The attenuation constants for the nth mode (symbolized here by α_1 and α_2) are given by

$$\alpha_1 = \pm\left(\mu_1\right)^{1/2} = \epsilon_1 U_1 e^{i\eta_1} = k_1 + i\ell_1 ,$$

$$\alpha_2 = \pm\left(\mu_2\right)^{1/2} = \epsilon_2 U_2 e^{i\eta_2} = k_2 + i\ell_2 ,$$

where

$$U_1 = E_1^{1/2}, \ U_2 = E_2^{1/2} , \eta_1 = \gamma_1/2 , \ \eta_2 = \gamma_2/2 ,$$

$$k_1 = \epsilon_1 U_1 \cos\eta_1 , \ \ell_1 = \epsilon_1 U_1 \sin\eta_1 ,$$

$$k_2 = \epsilon_2 U_2 \cos\eta_2 , \ \ell_2 = \epsilon_2 U_2 \sin\eta_2 ,$$

and ϵ_1 and ϵ_2 are chosen so that $\epsilon_1 \cos\eta_1$ and $\epsilon_2 \cos\eta_2$ are both negative ($\epsilon_1 = \pm 1$, $\epsilon_2 = \pm 1$).

Next, the following quantities are calculated:

$$\phi' = h - m \quad ,$$

$$g = -(f/q) = Ge^{i\nu} \quad ,$$

where

$$G = -f/\left(\sigma^2 + \Omega^2\right)^{1/2} = -\left(f/A_1\right) \quad ,$$

$$\nu = -\theta_1 \quad .$$

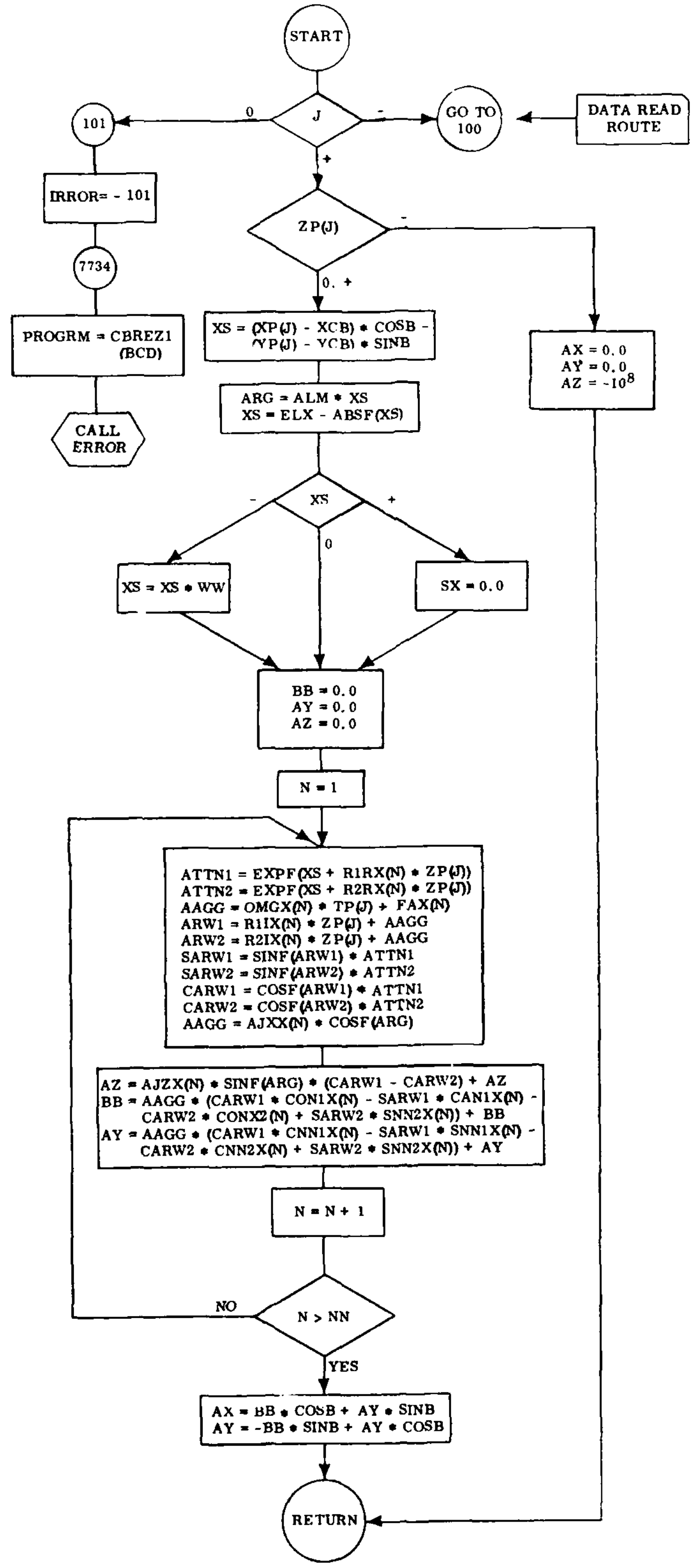
At this point all the mode-dependent constants necessary to describe the nth mode wind field have been computed.

Subroutine HEIGHT (X, Y, H) (FC-16)

Subroutine HEIGHT puts into argument H the topographic height at horizontal position X, Y. It makes use of the in-core topographic data block in arrays S(I, J) and SUBSID(K), and data from the topographic table of contents as transferred to block limit words BXLL, BYLL, BXLU, and BYLU, as well as the block grid interval as found in GRINT and the overall topography coordinate limits TXLL, TYLL, TXLU, and TYLU. (See the discussion of the topography data input in the User Information section.)

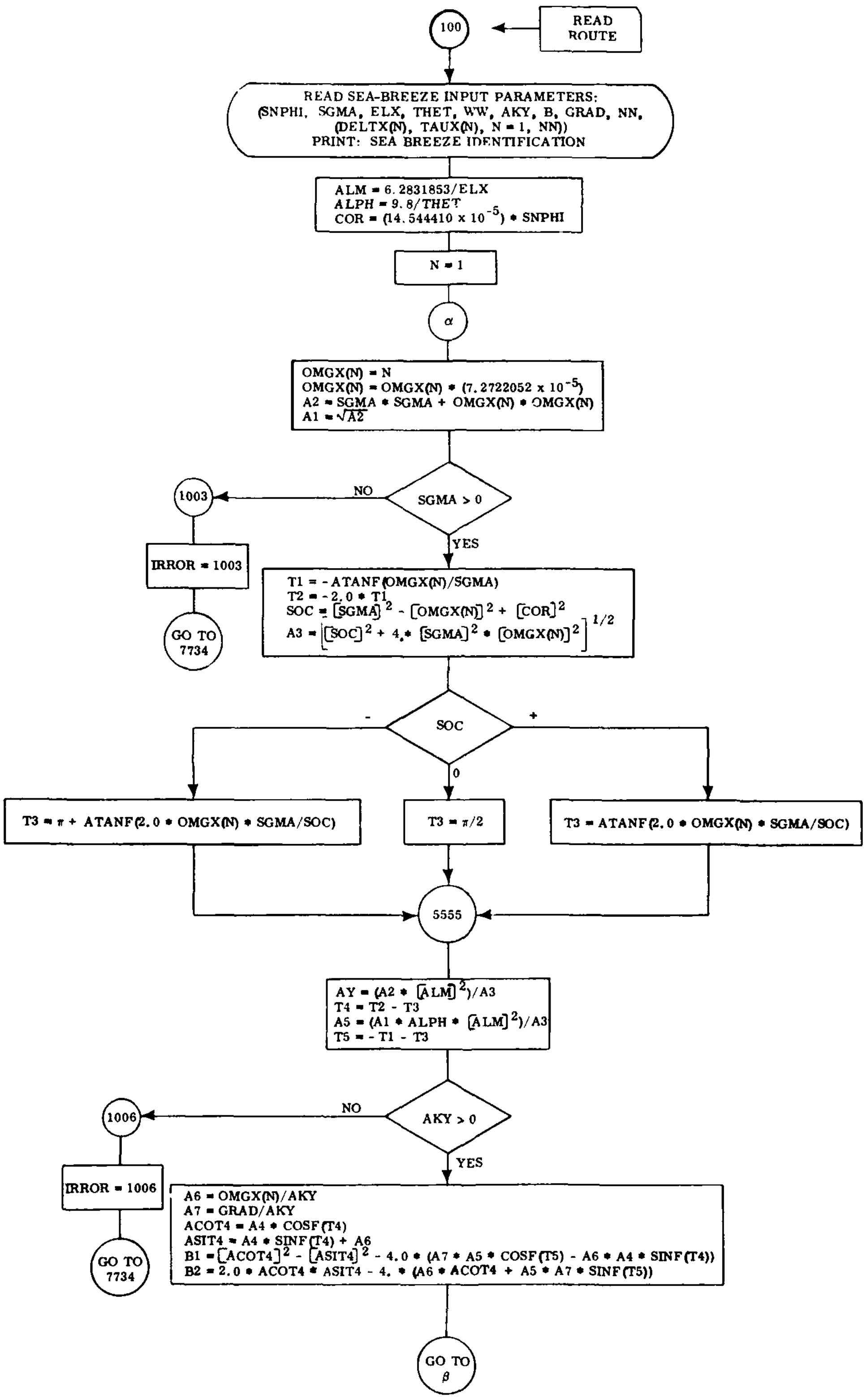
Upon entrance, the particle coordinates X and Y are checked first to determine if the particle is over the in-core topography block. If the particle is over in-core topo, a transfer is made to statement number 11 where retrieval begins. If it is not, a second check is made to determine if the particle is over any specified topography block. If it is over a topography block not currently in core, this is indicated by setting H = - 10000. If it is over undefined topography then it sets H = - 20000. In either case, control then returns to the calling program.

Actual height retrieval begins at statement number 11 with the computation of basic retrieval indices I and J. I and J are respectively the indices of the regular grid square of side GRINT in which the point XX, YY is located. The point BXLL, BYLL is the southwesternmost point with the in-core topo data block and it is


START
J
0
-
+
101
GO TO 100
DATA READ ROUTE
IRROR= - 101
7734
PROGRM = CBREZ1 (BCD)
CALL ERROR
ZP(J)
-
0. +
XS = (XP(J) - XCB) * COSB - (YP(J) - YCB) * SINB
AX = 0.0
AY = 0.0
AZ = -10^8
ARG = ALM * XS
XS = ELX - ABSF(XS)
XS
-
0
+
XS = XS * WW
SX = 0.0
BB = 0.0
AY = 0.0
AZ = 0.0
N = 1
ATTN1 = EXPF(XS + R1RX(N) * ZP(J))
ATTN2 = EXPF(XS + R2RX(N) * ZP(J))
AAGG = OMGX(N) * TP(J) + FAX(N)
ARW1 = R1IX(N) * ZP(J) + AAGG
ARW2 = R2IX(N) * ZP(J) + AAGG
SARW1 = SINF(ARW1) * ATTN1
SARW2 = SINF(ARW2) * ATTN2
CARW1 = COSF(ARW1) * ATTN1
CARW2 = COSF(ARW2) * ATTN2
AAGG = AJXX(N) * COSF(ARG)
AZ = AJZX(N) * SINF(ARG) * (CARW1 - CARW2) + AZ
BB = AAGG * (CARW1 * CON1X(N) - SARW1 * CAN1X(N) - CARW2 * CONX2(N) + SARW2 * SNN2X(N)) + BB
AY = AAGG * (CARW1 * CNN1X(N) - SARW1 * SNN1X(N) - CARW2 * CNN2X(N) + SARW2 * SNN2X(N)) + AY
N = N + 1
NO
N > NN
YES
AX = BB * COSB + AY * SINB
AY = -BB * SINB + AY * COSB
RETURN

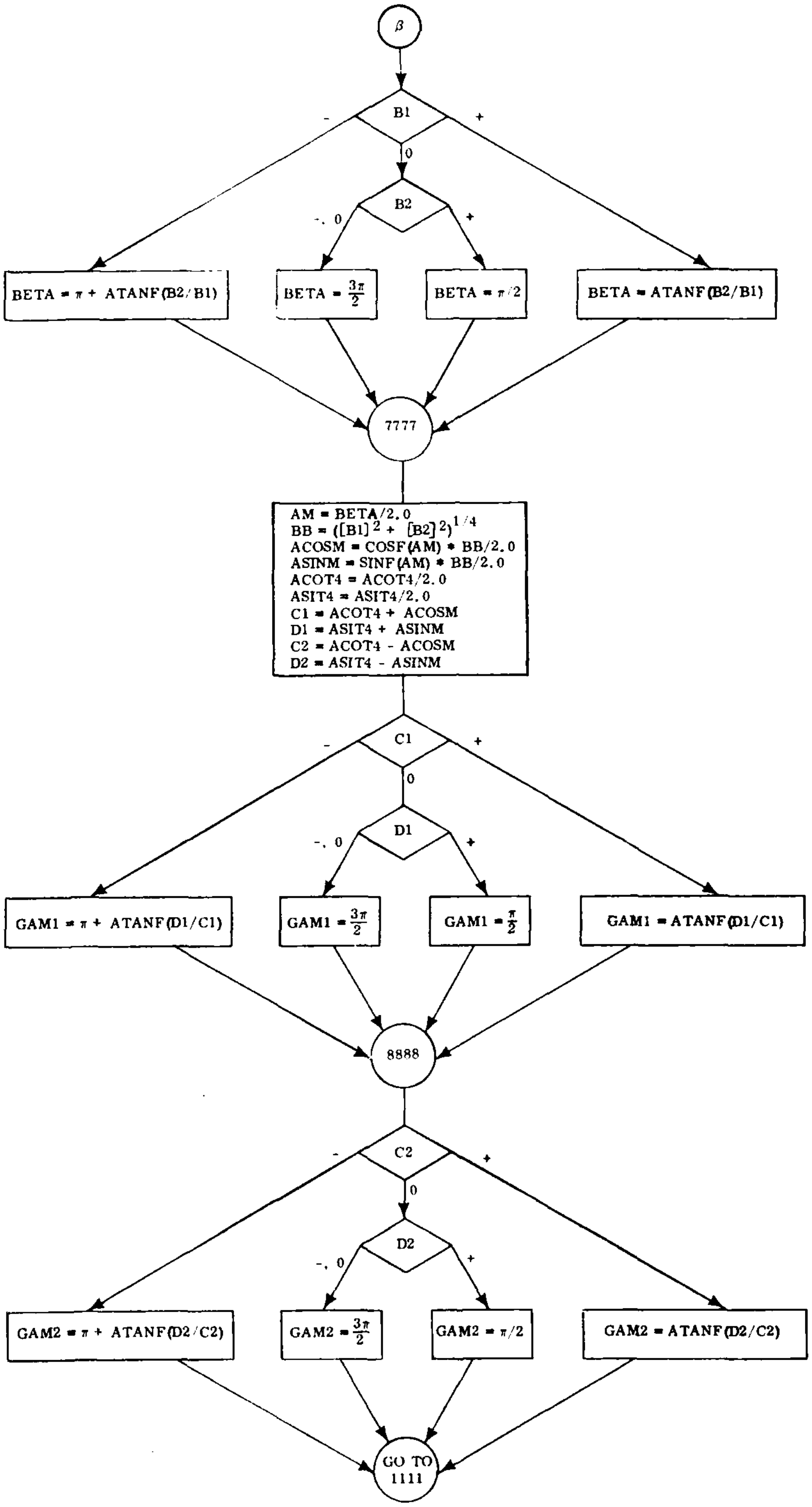
(a)

FC-15. Flow Charts for Subroutine CBREZ1


100
READ ROUTE
READ SEA-BREEZE INPUT PARAMETERS:
(SNPHI, SGMA, ELX, THET, WW, AKY, B, GRAD, NN,
(DELTX(N), TAUX(N), N = 1, NN))
PRINT: SEA BREEZE IDENTIFICATION
ALM = 6.2831853/ELX
ALPH = 9.8/THET
COR = (14.544410 x 10^-5) * SNPHI
N = 1
α
OMGX(N) = N
OMGX(N) = OMGX(N) * (7.2722052 x 10^-5)
A2 = SGMA * SGMA + OMGX(N) * OMGX(N)
A1 = √A2
SGMA > 0
NO
1003
IRROR = 1003
GO TO 7734
YES
T1 = - ATANF(OMGX(N)/SGMA)
T2 = - 2.0 * T1
SOC = [SGMA]^2 - [OMGX(N)]^2 + [COR]^2
A3 = [[SOC]^2 + 4.* [SGMA]^2 * [OMGX(N)]^2]^1/2
SOC
-
0
+
T3 = π + ATANF(2.0 * OMGX(N) * SGMA/SOC)
T3 = π/2
T3 = ATANF(2.0 * OMGX(N) * SGMA/SOC)
5555
AY = (A2 * [ALM]^2)/A3
T4 = T2 - T3
A5 = (A1 * ALPH * [ALM]^2)/A3
T5 = - T1 - T3
AKY > 0
NO
1006
IRROR = 1006
GO TO 7734
YES
A6 = OMGX(N)/AKY
A7 = GRAD/AKY
ACOT4 = A4 * COSF(T4)
ASIT4 = A4 * SINF(T4) + A6
B1 = [ACOT4]^2 - [ASIT4]^2 - 4.0 * (A7 * A5 * COSF(T5) - A6 * A4 * SINF(T4))
B2 = 2.0 * ACOT4 * ASIT4 - 4. * (A6 * ACOT4 + A5 * A7 * SINF(T5))
GO TO β

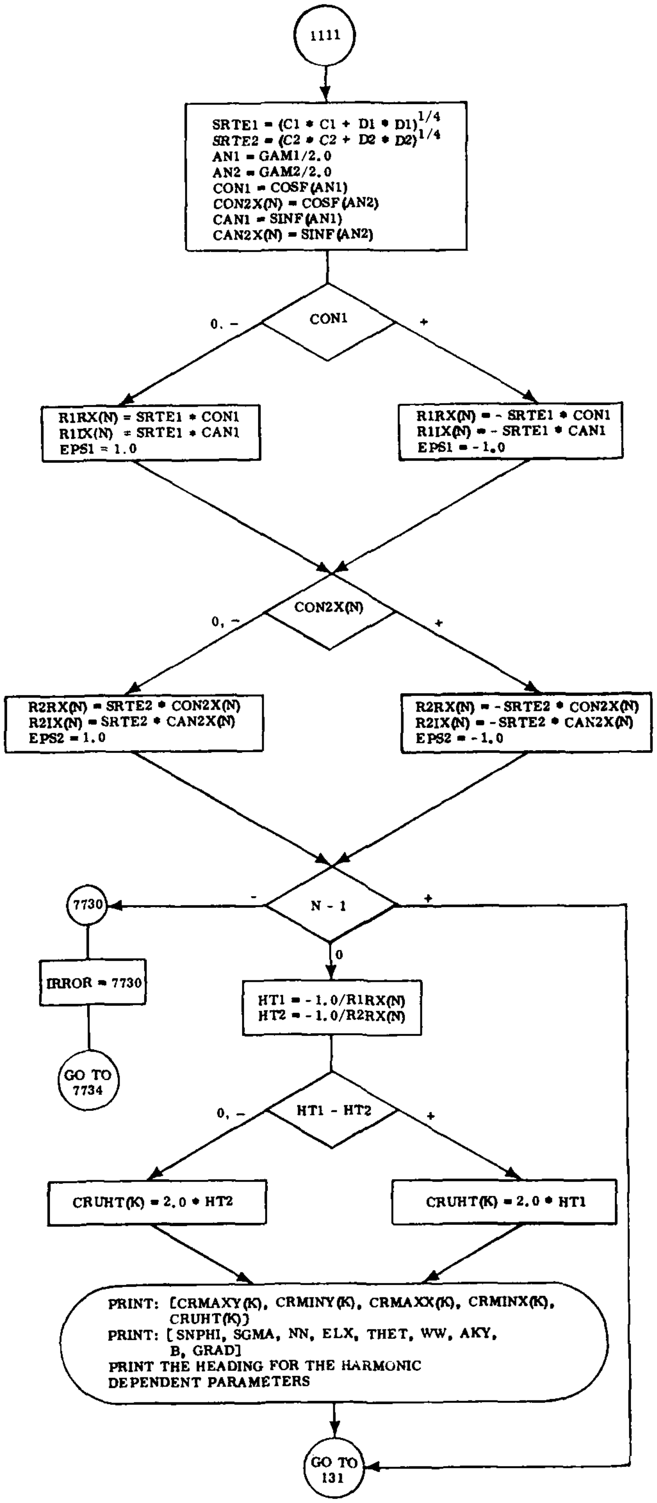
(b)

FC-15. (Continued) Flow Charts for Subroutine CBREZ1



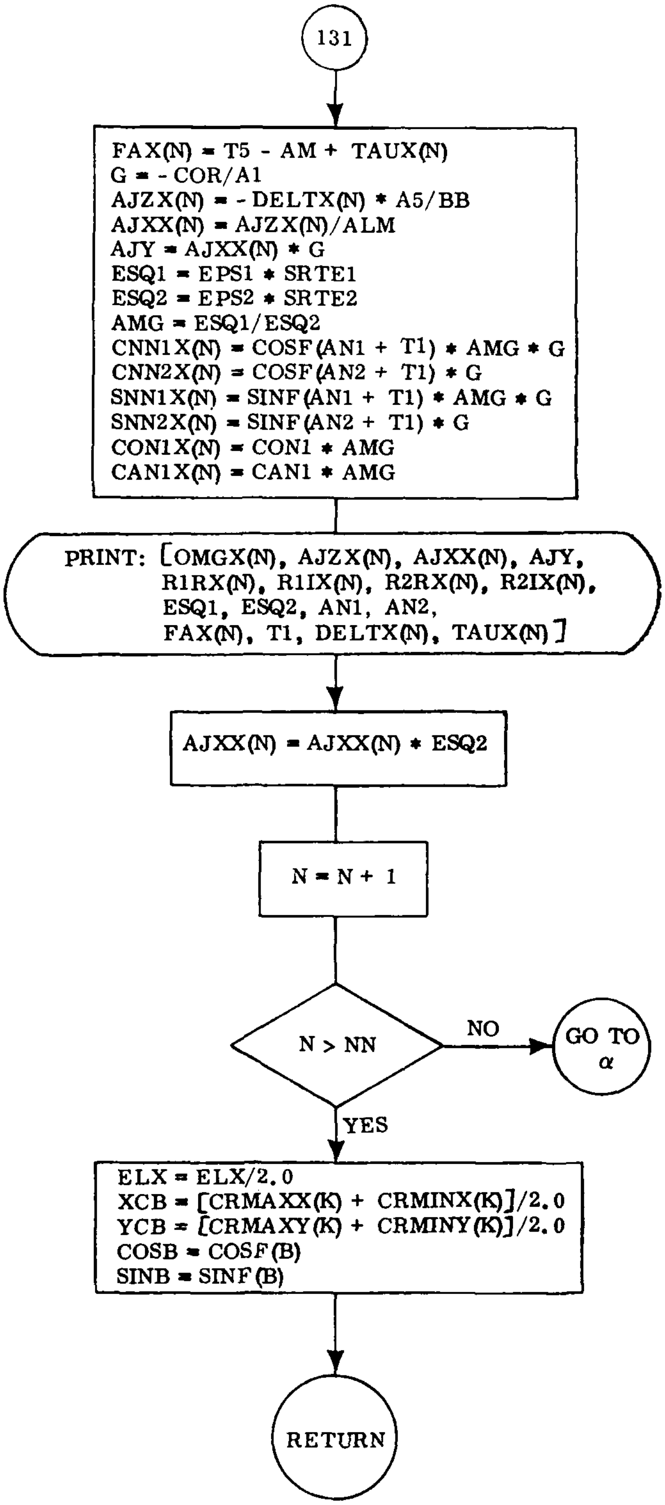
(c)

FC-15. (Continued) Flow Charts for Subroutine CBREZ1



(d)

FC-15. (Continued) Flow Charts for Subroutine CBREZ1

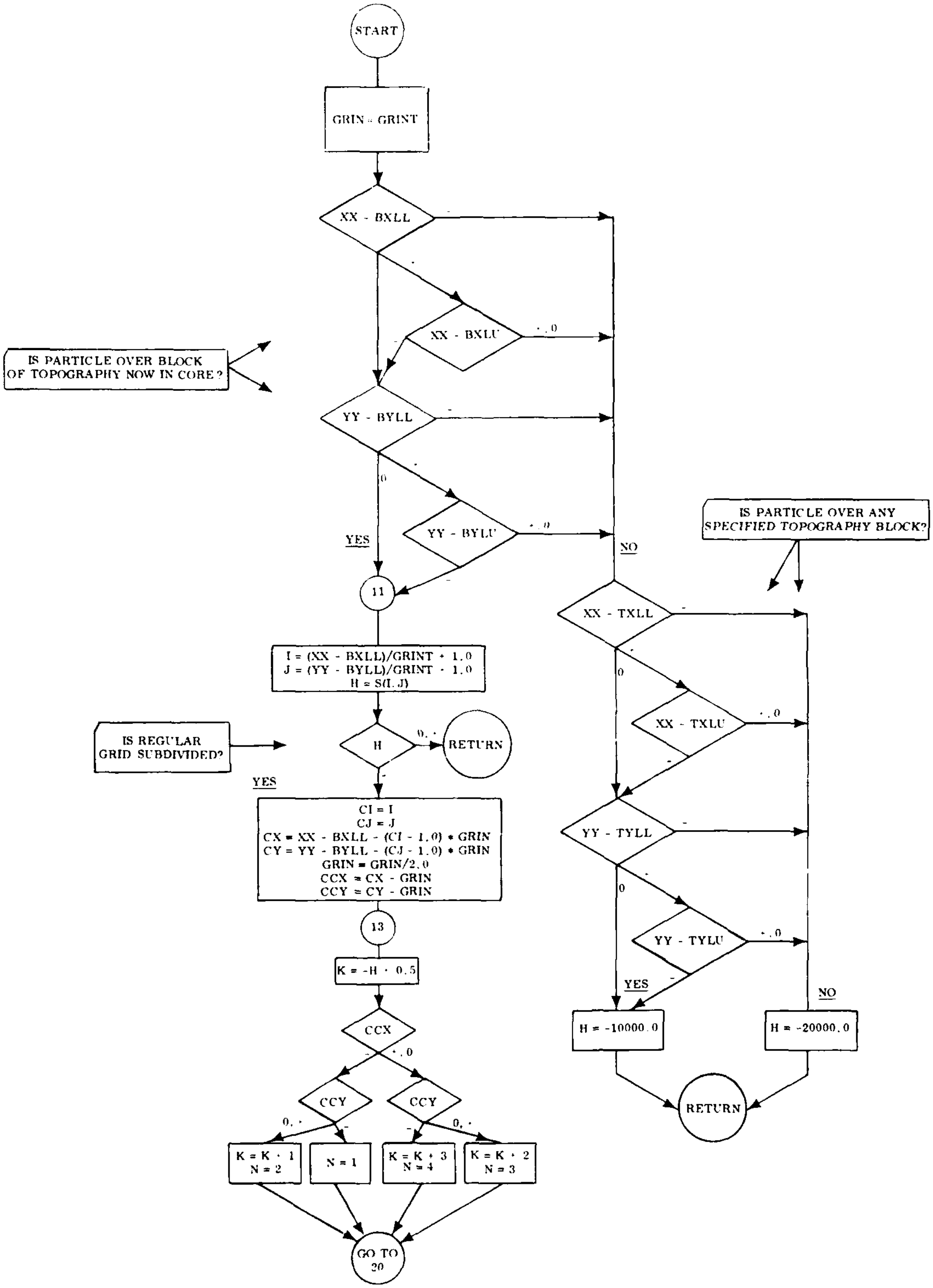

131
FAX(N) = T5 - AM + TAUX(N)
G = - COR/A1
AJZX(N) = - DELTX(N) * A5/BB
AJXX(N) = AJZX(N)/ALM
AJY = AJXX(N) * G
ESQ1 = EPS1 * SRTE1
ESQ2 = EPS2 * SRTE2
AMG = ESQ1/ESQ2
CNN1X(N) = COSF(AN1 + T1) * AMG * G
CNN2X(N) = COSF(AN2 + T1) * G
SNN1X(N) = SINF(AN1 + T1) * AMG * G
SNN2X(N) = SINF(AN2 + T1) * G
CON1X(N) = CON1 * AMG
CAN1X(N) = CAN1 * AMG
PRINT: [OMGX(N), AJZX(N), AJXX(N), AJY,
R1RX(N), R1IX(N), R2RX(N), R2IX(N),
ESQ1, ESQ2, AN1, AN2,
FAX(N), T1, DELTX(N), TAUX(N)]
AJXX(N) = AJXX(N) * ESQ2
N = N + 1
N > NN
NO
GO TO α
YES
ELX = ELX/2.0
XCB = [CRMAXX(K) + CRMINX(K)]/2.0
YCB = [CRMAXY(K) + CRMINY(K)]/2.0
COSB = COSF(B)
SINB = SINF(B)
RETURN

(e)

FC-15. (Continued) Flow Charts for Subroutine CBREZ1

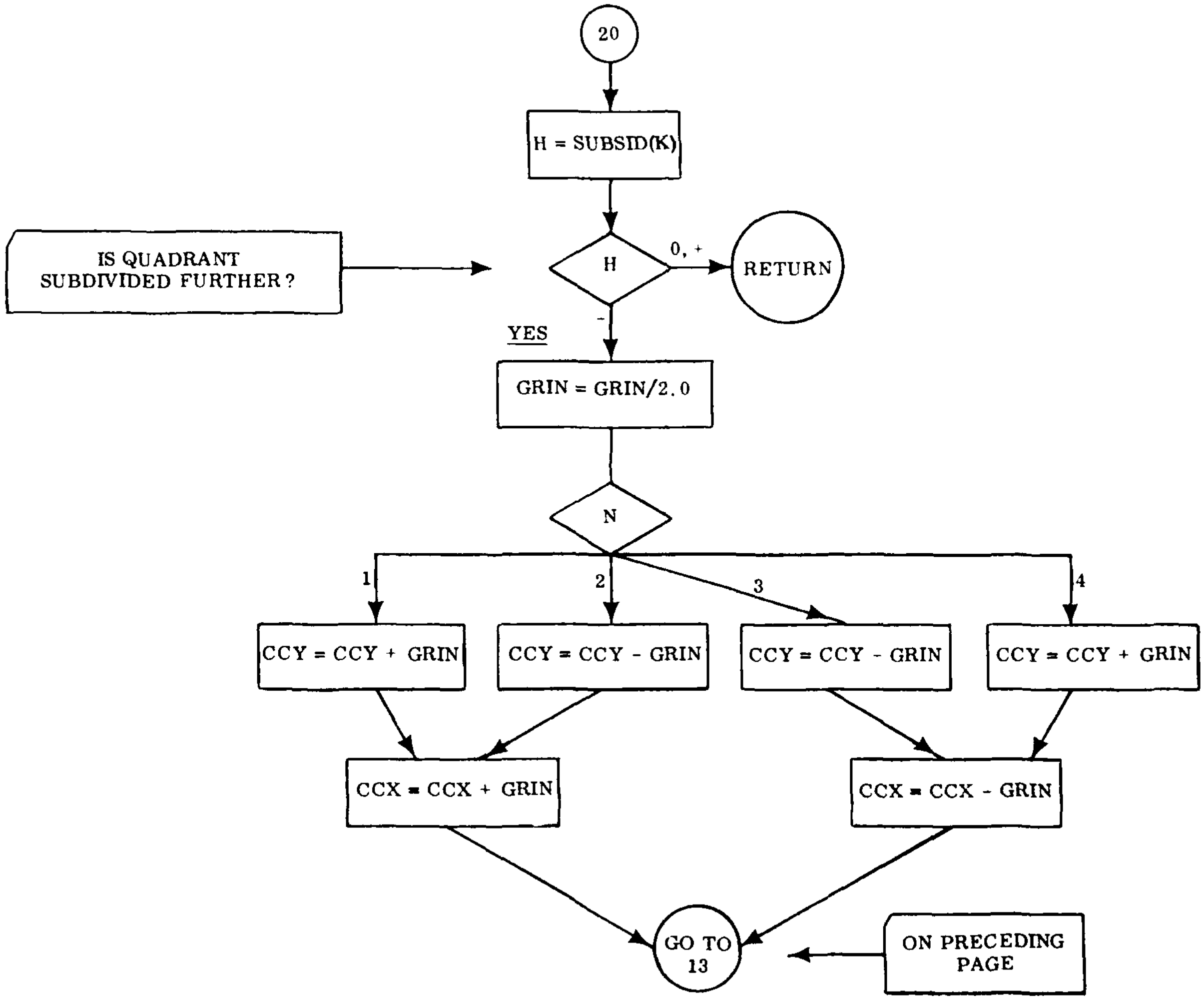
located in grid square (1, 1), the height data of which is located in memory word S(1, 1). According to the storage convention of the piecewise-planar topography, if H = S(I, J) is positive, it is the height of the topography in the cell (I, J) and thus the height which is being sought. If, on the other hand, H is negative, the cell (I, J) is subdivided further and |S(I, J)| is the address (index) of the place in array SUBSID(K) where the data for the subdivided cell begins. If H is negative, the program makes preparations to retrieve topographic data from array SUBSID(K), and then between statements number 13 and 20 computes retrieval index K and control integer N. Whenever a cell (topographic unit) is subdivided it is always divided into four equal-sized squares (quadrants). The integer N identifies the quadrant that contains the point XX, YY.

The sign convention of S(I, J) also applies within array SUBSID, and if a negative entry is encountered, a further subdivision of the cell containing the point XX, YY is indicated. In that case coordinate adjustments are made again, and the program returns to statement 13 where the new retrieval index K is computed and used. Eventually HEIGHT will find a positive height H and return to the calling program.



(a)

FC-16. Flow Charts for Subroutine HEIGHT



(b)

FC-16. (Continued) Flow Charts for Subroutine HEIGHT

USER INFORMATION

Input Description

General

The Transport Module requires two kinds of input: (1) a binary tape output from the Cloud Rise-Transport Interface Module, and (2) a set of card inputs to be read from the system (IBSYS) input tape. The binary input tape carries the identifier IPARIN so that the program can ascertain that the correct tape has been mounted. This tape provides a detailed description of a large number of cloud subdivisions that are ready to be processed by the Transport Module. The Cloud Rise-Transport Interface Module produces two structurally identical binary output tapes, both labeled IPARIN, that (1) describe an axially symmetric cloud defined at some time of stabilization and (2) describe an asymmetric cloud resulting from the adjustment of the stabilized cloud in accordance with the winds that existed during the period of cloud rise. Either one of these tapes can be used as input to the Transport Module. It is important to note that in neither case are all cloud subdivisions defined at the same time. The content and structure of tape IPARIN is described in detail in Table 5.

Card inputs to the Transport Module consist of two classes: first, identification and control information; and second, wind-field information. Since the wind-field data required depends on what options are to be used, we cannot describe the deck of card inputs to the Transport Module in an invariant form; therefore, we shall describe first only the invariant portion of the deck and later provide individual descriptions of the data required by the various options.

The first card input required for the Transport Module is an identification card on which the user may punch any alphanumeric characters to identify his run of the Transport Module. The second card contains the values of the array of parameters for use in controlling the execution of the Transport Module. Only 8 of the 18 elements of the array IC have been given functions at this time and their uses are summarized in Table 6. The remaining parameters are for use in future improvements or simplifications of the Transport Module.

TABLE 5

BINARY INPUT
Tape IPARIN

Logical Binary Record	Record Contents	Variable Names
1	Tape identification word (IPARIN), spare, x and y coordinates of ground zero, shot time, cloud subdivision edge length, spare	DENTI, NSP, XGZ, YGZ, TGZ, BZ, NCL
2	Detonation parameters: yield, cloud soil burden, soil solidification temperature, soil solidification time, ln(SD),[†] spares	FW, SSAM, SLDTMP, TMSD, SIGMA, SPARE1, SPARE2, SPARE3
3	LINK4 run identification	PSEID(J), J = 1, 12
4	Cloud-rise identification	CRID(J), J = 1, 12
5	Initial-conditions run identification	DETID(J), J = 1, 12
6	Fallout particle density	ROPART
7	Number of particle size ranges	NPS
8	Central particle size, associated mass, associated activity, * and surface-to-volume ratio for each size range	PS(I), A(I), PACT(I), SV(I), I = 1, NPS
9	Number of atmospheric strata	NAT
10	Atmospheric viscosity and density for each stratum	ATEMP (I), RHO(I), I = 1, NAT
11	Number of particles described in the first data block	NP
12	Particle data for first data block: x, y, z, and time coordinates, particle size, mass per unit area of cloud subdivision bottom	XPAR(I), YPAR(I), ZPAR(I), TP(I), PSIZ (I), SMAS(I), I = 1, NP
13	Same as record 11 for the second data block	
14	Same as record 12 for the second data block	
.		
.		
.		
M	Tape termination indicator	NP = O
M + 1	End of file	

*Not yet calculated unless the user has provided a LINK3 particle activity calculation.

[†] See LINK1 glossary in DASA-1800-II.

TABLE 6

DESCRIPTION OF THE TRANSPORT CONTROL ARRAY —
IC(I), I = 1, 8

I	Function
1	IC(1) > 0, suppresses usage of topography tape, IHTOPO, and a planar topography is assumed.
2	IC(2) > 0, suppresses usage of off-topo secondary tape, IOTOPO
3	IC(3) > 0, suppresses usage of out-of-wind-field secondary tape, IOWIND
4	IC(4) > 0, suppresses usage of time-boundary secondary tape, IPAROT
5	IC(5) > 0, suppresses usage of all secondary tapes
6	IC(6) < 1, no transport traces are printed IC(6) = 1, in-core particle arrays are printed following read-in of each block of particles from IPARIN (see p. 78) IC(6) > 1, in addition, a print-out is executed following each transport increment (see p. 78)
7	IC(7) = 1, causes the computed wind field to be printed each time it is updated (see Table 13)
8	IC(8) = 0, causes a listing of lost particles (see Table 2) whenever a group of lost particles are discarded by subroutine DUMPP.

The third card indicates the latest simulated time at which the user wishes the transport process to terminate. The fourth card indicates the altitude of the deposition surface (topography) in the event that the planar topography option of the Transport Module is to be used (IC(1) = 0). The fifth card is an identification card on which the user may punch any alphanumeric characters to identify the forthcoming wind data set. Table 7 summarizes the card inputs for identification and control of the Transport Module.

TABLE 7

CARD INPUTS FOR IDENTIFICATION AND CONTROL OF THE TRANSPORT MODULE

Card Number	Content	Variable Names and Format
1	Transport model run identification	TID(J), J=1, 12 (12A6)
2	Control integer array	IC(J), J=1, 18(18I4)
3	Transport time limit (sec)	TLIMIT (F10. 5)
4	Altitude of planar topography. This card is to be omitted if a topography input tape is used (m).	TTOPO (F10. 5)
5	Wind-field data set identification card	WID(J); J=1, 12 (12A6)

The remaining card inputs describe the wind field through which particle transport is to be carried out. As mentioned previously, temporal variation of the atmosphere is achieved by periodically updating the entire wind field description. Input data is required for each updating of the wind field, but since the form of the required data deck is the same in each case we shall describe it only once.

MKWIND Data

The first card contains the values of parameters ENDTIM, the time (seconds) at which the forthcoming data set should be updated, and ALPHA and BETA empirical parameters which the program uses for distance weighting (see Eq. (21)).

The second card contains NN, the number of data vectors that are to be used in computing the vector estimate for each wind cell of the wind field. The NN data vectors that are closest to the grid point are used. Also on the second card is the parameter NCODE which identifies the computation method to be used in accordance with Table 8.

TABLE 8

WIND-FIELD COMPUTATION METHODS
SPECIFIED BY NCODE

NCODE Value	Method
1	Use preferential weighting method with the nearest NN data vectors
2	Set NN = 1 and use code number 1 (this is the nearest station method)
3	Set NN equal to the total number of data vectors available and use code number 1
4	Use the least-squares method to fit to a linear model of the atmosphere. In this case NN must be greater than 3.

In the next series of cards the program reads the user's specifications for the subdivisions of the stratum and cell atmospheric structure. Each card of this set contains the altitude of a stratum bottom (meters), the width of the wind cell bottom edges (assumed square) within this stratum (meters), and four coordinates that indicate the horizontal limits of this stratum (meters). Here also, the data cards need not be in ascending order of altitude since they are sorted into that order by the program after being read, but the end of the data set must be marked by a card having the value 999999.0 in the stratum base altitude position.

In the next series of cards the program reads all wind data vectors, one to a card. The position of each vector is specified by three coordinates; its magnitude and direction are specified by three vector components. The order of these cards is completely immaterial, but the end of the deck of data vectors must be marked by a card having the value 999999.0 in the vector altitude position. A maximum of 299 data vectors may be provided. Table 9 summarizes the card input to MKWIND.

TABLE 9

SUMMARY OF CARD INPUTS TO SUBROUTINE MKWIND

Card Number	Content	Variable Names and Format
1	Time (seconds) at which the forthcoming wind data set is to be updated, α, β (Eq. 21)	ENDTIM. ALPHA, BETA (3F10.3)
2	The number of nearest data vectors that the user wishes the program to use in making a vector estimate for each grid point, the identification number of the computation method that the user wishes to be used in making grid point vector estimates (see Table 8).	NN, NCODE (2I4)
3	Altitude of first stratum base (meters above MSL), width of wind cells in the stratum, coordinate of planes limiting this stratum on the west, south, east, and north respectively. (A right-handed coordinate system is used.)	BOTHIT(J) WGRINT(J), WLLX(J), WLLY(J), WURX(J), WURY(J), J = 1 (6F10.3)
4	Same as card 3 but for second stratum	Same as card 3 but for J = 2
. . .	. . .	. . .
Last of Subdivision Specifications	The end of the subdivision specifications is marked by the number 999999.0 in the stratum base altitude place	
First Data Vector	Vector altitude, X coordinate, Y coordinate, X-velocity component, Y-velocity component, Z-velocity component (A west wind (from the west) has a positive X component; a south wind has a positive Y component; the Z direction is positive upward) (m and m/sec)	ZS(J), XS(J), YS(J), SX(J), SY(J), SZ(J), J = 1 (6F12.3)
Second Data Vector	Same as preceding card but for second data vector	Same as preceding card but for J = 2
. . .	. . .	. . .
Last Vector Card	The end of the deck of data vectors is marked by the number 999999.0 in the vector altitude position	

Local Circulation System Data

Two types of data are required for the description of local circulation systems to be included within a transport atmosphere. First are data that specify the sizes and locations of all local circulation cells, and second are the data that describe the wind fields within each of the local circulation cells. Data of the first type are read by subroutine RDCIRS, while the data actually describing the local systems must be read by the corresponding local circulation system programs. To achieve this the local system programs have dual purposes — dependent upon an argument value, these programs will either (1) read the required input data from the system (IBSYS) input tape (and precompute certain parameters) or (2) compute the wind vector at a position specified in its argument list.

TABLE 10

CARD INPUTS TO SUBROUTINE RDCIRS

Card Number	Content	Variable Names and Format

1	Coordinates of planes that bound the Jth local circulation system cell on the west, east, south, and north, respectively, and the circulation type identifier.	CRMINX(J), CRMAXX(J)
		CRMINY(J), CRMAXY(J)
		NCRTYP(J)
		(4E12.5, I3)

Last Card	The end of the deck of cell descriptions is marked by a card having a circulation type identifier of zero (a blank card will do). Note that if no local circulation cells are to be used in a transport run, a blank card must still be provided to RDCIRS.	Blank

Table 10 summarizes the input cards to subroutine RDCIRS. The first card read by RDCIRS contains the coordinates of the four planes (perpendicular to the coordinate axes) that bound a local circulation cell and also a number that identifies the type of associated local circulation system according to the following designations:

Idcntification Number	Local Circulation Type
0	Marks the end of the set of local circulation cell descriptions
1	Mountain wind (MTWND1)
2	Ridge wind (RGWND1)
3	See breeze (CBREZ1)
4	Not assigned
5	Not assigned

The reading of all descriptions is terminated when a blank card is encountered; therefore, if no local circulation systems are in use, a blank card is still required by RDCIRS. The maximum allowable number of local circulation systems is currently set at 5.

RDCIRS establishes the order of the entries in a table of local cell descriptions by storing the cell data sequentially as it is read. Later calls are made to the associated local circulation system programs in the established sequence so that these programs may read the data that they require. Table 11 presents a summary of the data decks required by each of the three available local circulation programs. More detailed descriptions of these data may be found in the individual discussions of the local circulation system programs. (Mks units are used.)

Topography Data

Two basically different forms of topography may be specified for use by the Transport Module in regions not covered by local circulation systems. They are referred to here as fully planar topography (a single plane) and piecewise-planar topography (many segments of planes). The choice of method of topographic description is communicated to the Transport Module by the user in the control parameter IC(1) (see Table 6) which must be given the value 1 if the fully planar option is desired and 0 if not. In the fully planar option, the program merely reads from a

TABLE 11

SUMMARY OF CARD INPUTS TO SUBROUTINES MTWND1, RGWND1, AND CBREZ1

Card Number	Content	Variable Names and Format
	Subroutine MTWND1	
1	X and Y coordinates. Maximum height, and half width of the Jth mountain	XM(J), YM(J), H(J), A(J), (4F10.3), J = 1
2	Same as card 1 but for 2nd mountain	Same as card 1 but for J = 2
. . .	. . .	. . .
Last Card	The end of the deck of mountain descriptions is indicated by a card having a zero in the mountain height position	
	Subroutine RGWND1	
1	X and Y coordinates of a point on the 1st ridge line, height of 1st ridge, half width of 1st ridge, orientation angle of 1st ridge (radians clockwise from time north)	XM(J), YM(J), H(J), A(J), B(J), J = 1 (5F10.3)
2	Same as card 1 but for 2nd ridge	Same as card 1 but for J = 2
. . .	. . .	. . .
Last Card	The end of the deck of ridge description is marked by a card having a zero in its ridge height position	
	Subroutine CBREZ1	
1	Sine of the latitude of the sea-breeze cell, Guldberg-Mohn friction parameter, the total extent of the sea breeze, average ground temperature	SNPHI, SGMA, ELX, THET, (4F10.3)
2	Wind-field extrapolation attenuation constant, thermal eddy diffusivity, coastline orientation angle, unperturbed temperature gradient, number of harmonics used in temperature-time description	WW, AKY, B, GRAD, NN,(4F10.3, I10)
3	Magnitude of 1st temperature differential, phase of 1st temperature differential	DELTX(N), TAUX(N), N = 1
4	Same as card 3 but for 2nd harmonic	Same as card 3 but for N = 2
. . .	. . .	. . .

card the height of the planar topographic surface and uses it throughout transport. If the piecewise-planar option is specified, the program expects that a topographic data tape has been prepared and is available for use. This tape carries the identification word IHTOPO and its data structure is indicated in Table 12. Complete details are given in Appendix C. (Mks units are used.)

TABLE 12

THE BINARY TOPOGRAPHY TAPE DATA

Record Number	Content	Variable Names
1	Tape identification symbol (IHTOPO), overall topography area limits, and the number of data blocks	DENTI, TXLL, TXLU, TYLL, TYLU, NBLCK
2	Arbitrary topographic identification card image	TOPID(J), J = 1, 12
3	Topography table of contents (first part) for all data blocks	TOPOLM(I, J), I = 1, 4, J = 1, NBLCK
4	Topography table of contents (second part) for all data blocks	ITOPLM(I, J), I = 1, 3, J = 1, NBLCK
5	2-D table of data for first data block	S(I, J), I = 1, II, J = 1, JJ
6	1-D table of data for first data block	SUBSID(K), K = 1, KK
7 8	Same as records 5 and 6 but for second data block	
. . .		
N	End of file	

The Transport Module uses subroutine RDTOPO to read blocks of topographic data into memory from the tape IHTOPO. Subroutine HEIGHT is used to determine the elevation of the topographic surface at the horizontal position of a particle. Two other programs, TOPIN and DATERR, which are not strictly part of the Transport Module, have been written to prepare and check the topographic data tape and to write the piecewise-planar topography tape IHTOPO Since these programs are out of the main stream of the Transport Module, their inputs, operations, and outputs will not be described here, but rather are dealt with in Appendix C However the contents of tape IHTOPO are as follows

The topographic data must be divided into blocks and only one block at a time can be accommodated in core storage during transport. With reference to Table 12, we see that the first record consists of the tape identifier, the coordinate limits of the area covered by all the data blocks on the complete topography tape, and the number of topography data blocks on the tape. The second record consists of a Hollerith card image that contains a descriptive comment that identifies the particular topographic data on the tape To describe the contents of the remaining records, we must briefly review, as follows, the nature of the topography description

1. Consider the topographic unit to be a surface segment that projects a square area onto the $z = 0$ plane such that the sides of the projected square are parallel to the coordinate axes (north-south and east-west)

2. Location coordinates of all topography units are specified in the $z = 0$ (horizontal) plane of the macrowind-field coordinate system.

3 Topography descriptions are arranged on tape IHTOPO in data blocks, each of which consists of arrays ((S(I, J), I = 1, II) J = 1, JJ) and (SUBSID(K), K = 1, KK).

4. Array S represents a rectangular area in the $z = 0$ plane (with sides parallel to the x and y axes) that otherwise is arbitrarily placed within the limits of the overall topo area. Its minimum x and y coordinates are BXLL and BYLL (in meters). It is subdivided by a square grid with interval GRINT (meters) Each element S(I, J) of array S has the following significance:

   a. If S(I, J) is positive, then S(I, J) is the altitude of the (I, J)th topography unit it represents in the array area (meters above mean sea level).

   b. If S(I, J) is negative, then the fixed-point equivalent of $|S(I, J)|$ is the index of an element in array SUBSID that is the first element of a quartet (see item 5 below).

The indices I and J of the S(I, J) array represent increments of distance GRINT along the x and y axes respectively. S(1, 1) represents the grid element in the lower left corner of the area. S(2, 1) is the next element to the right of the corner, S(1, 2) is the element just above the corner, etc.

5. Array SUBSID consists of a sequence of groups of four elements (quartets) each of which represents the four square areas (topography units) resulting from an equal subdivision of a topography unit. Each element SUBSID(K) of array SUBSID has the following significance:

   a. If SUBSID(K) is positive, it is the altitude of the topography unit it represents (meters above mean sea level).

   b. If SUBSID(K) is negative, then the fixed-point equivalent of $|\mathrm{SUBSID(K)}|$ is the index of an element in array SUBSID that is the first element of a quartet.

We see that array SUBSID allows (in principle) an unlimited capability for successive subdivision of the original topography units defined in array S. Furthermore, a unique *altitude is specified for each* topography unit that results finally from the successive subdivision process. The sequence numbering of quartet members is as follows: lower left SUBSID(K), upper left SUBSID(K+1), upper right SUBSID(K+2), lower right SUBSID(K+3).

The correspondence between arrays S and SUBSID is as follows. Picture the array S to be set up in the fashion of a conventional matrix

$$\begin{array}{ccccc}
S(1,1) & S(1,2) & S(1,3) & \ldots & S(I,JJ) \\
S(2,1) & S(2,2) & S(2,3) & \ldots & S(2,JJ) \\
\vdots & & \vdots & & \vdots \\
S(II,1) & S(II,2) & S(II,3) & \ldots & S(II,JJ)
\end{array}$$

The sequence of quartets in the array SUBSID is determined by scanning through each row of the S matrix, in its numerical sequence, from left to right. Each negative element so encountered in the matrix starts the next quartet in SUBSID.

With reference to the discussion above we now can define records 3 and 4 on tape IHTOPO. Together these records provide a complete table of contents for the remainder of the tape by defining all of the data blocks on the tape. For each of the arrays TOPOLM(I, J) and ITOPLM(I, J), the index J identifies the data block sequence number (J = 1, 2, 3, 4). The index I specifies the parameters:

I	TOPOLM	ITOPLM
1	BXLL	II
2	BYLL	JJ
3	GRINT	KK
4	TTOPO	

The variable TTOPO gives the maximum topography altitude specified in the data block. All distances are specified in meters, and altitudes in meters above mean sea level.

Then on the tape IHTOPO the arrays S and SUBSID follow for each data block.

Output Description

Printed Output

The printed output of the Transport Module is largely self-explanatory since extensive labeling is done. Table 13 presents a summary of this output. Not included are the (optional) transport trace printouts which are described in the discussion of subroutine LINK7.

Binary Output

The primary output of the Transport Module is a magnetic tape containing a binary mode complete description of all cloud subdivisions that landed during the transport run. In addition, the Transport Module prepares printed output designed to identify and describe the transport run in sufficient detail so that the resulting

TABLE 13

PRINTED OUTPUT OF THE TRANSPORT MODULE

Output Sequence	Content	Variable Names
1	Run identifiers for LINK1, LINK2, LINK4, and transport	DETID(J), J = 1, 12 CRID(J), J = 1, 12 PSEID(J), J=1,12 TID(J), J=1, 12
2	Transport control array (Table 6)	IC(J), J=1,18
3	Transport time limit (sec)	TLIMIT
4	Fallout particle density (kg/m^3)	ROPART
5	Topographic data: a. If continuous planar topography is specified, the topography altitude (meters) is printed. b. If a piecewise planar topography is specified, the topography tape (IHTOPO) identifier is printed.	 TTOPO TOPOID(J), J=1,12
6	Wind-field identifier	WID(J), J = 1,12
7	Atmospheric properties used for particle fall rate calculations: height of stratum bottom, viscosity, and density (mks units)	height not stored, ATEMP, RHO
8	Replacement time of the wind field whose description follows (items 9 and 10)(sec)	ENDTIM
9	Wind vector input data array: z, x, y coordinates, and x, y, z wind vector components (meters and meters sec^{-1})	ZS(J), XS(J), YS(J), VX(J), VY(J), VZ(J)
10	Macrowind-field definition input data array: bottom height of stratum,grid interval, minimum x and y coordinates,maximum x and y coordinates (all in meters)	BOTHIT(J), GRINT(J), WLLX(J), WLLY(J), WURX(J), WURY(J)
11	If IC(7) = 1, the wind vectors at each grid point of the macrowind field are printed in the following arrangement: Level (stratum) number, altitude of the bottom of the stratum, x components of all wind vectors in the southernmost east-west row, y components of all wind vectors in the same row, z components for all vectors in the same row, repeat for the next row, etc.; repeat for the next level, etc.	J, BOTHIT(J), VS, VY, VZ
12	A one line in-core particle array summary printout is executed on each pass through subroutine DUMPP:JTEST, JTEST1 (Table 2),number of blanks, number of grounded particles, number of lost particles, number of particles on the topography boundary, number of particles on the time boundary, and number of particles on the wind-field boundary.	JTEST, JTEST1, NFREE, NG, NLOST, NTO, NTI, NW
13	If IC(8) = 0, properties of all "lost particles" are printed: z, y, z coordinates, time, diameter, and mass per unit area.	XP, YP, ZP, TP, PS, FMAS

tape of grounded cl‍oud suodivisions can be used repetitively. This is achieved by printing the identifiers of all the sets of input data that were used by the Transport Module as well as recoiding some of the data directly. The content of the intermediate output tape produced by the Transport Module and subsequently used by the output processor as an input is set forth in Table 14. Mks units are used except for particle diameters which are in microns

Data Structures for Secondary Memory Tapes

Three secondary memory tapes may be used by the Transport Module to temporarily record descriptions of particles that have been transported as far as possible using the data currently available in primary memory but which are still to be transported further. In the event that room must be made in the Transport Module's particle arrays for incoming particle descriptions, the transported (but not yet grounded) particles may be collected and written out onto a tape for: (1) particles beyond the in-core memory topography, (2) particles beyond the in-core memory wind field, or (3) particles awaiting the next updating of the wind field. Since all of these tapes are subsequently put symbolically into the place of the regular particle input tape IPARIN, they must all have the same data structure as the particle data portion of IPARIN. That structure consists of pairs of data records arranged in sequence on the tape -- the first record of a pair is a count of the number of particle descriptions to be found in the second record of the pair. The end of the data set is always marked by a zero particle count record.

TABLE 14

THE GROUNDED PARTICLES TAPE, IPOUT
(Binary output of the Transport Module)

Logical Record Number	Record Content	Variable Names
1	Identification word (IPOUT), spare, time at which transport was terminated, width of cloud subdivisions at time of definition, and density of fallout particles	POUT, NCL, TLIMIT, BZ, ROPART
2	Fission yield, mass of soil lifted, solidification temperature, time of solidification, ln(SD)[†] and 3 spares	FW, SSAM, SLDTMP, TMSD, SIGMA, SPARE1, SPARE2, SPARE3
3	Run identifiers for Initial Conditions, Cloud Rise, Cloud Rise-Transport Interface, Transport, and Wind Field	(DETID(J), J=1, 12), (CRID(J), J=1, 12), (PSEID(J), J=1, 12), (TID(J), J=1, 12), (WID(J), J=1, 12)
4	Number of particle size ranges	NPS
5	Central particle size, associated mass, associated activity,[*] and surface-to-volume ratio for each size range	PS(J), A(J), PACT(J), SV(J), J=1, NPS
6	Number of atmospheric strata	NA
7	Atmospheric viscosity and density for each stratum	ATEMP(J), RHO(J), J=1, NA
8	Topography identifier	TOPID(J), J=1, 12
9	Number of particle (cloud subdivision) descriptions in the following data block	N
10	X coordinate, Y coordinate, time, particle size, and mass per unit area associated with each of N particles	NP(J), YP(J), TP(J), PS(J), FMAS(J), J=1, N
11	Same as record 9	
12	Same as record 10	
	Pairs of records like 9 and 10 are repeated until all grounded particles are recorded	
Last record	The end of the ground particles data set is indicated by a particle count of zero	N=0

[*] Not yet calculated unless the user has provided a LINK3 particle activity calculation

[†] See LINK1 glossary in DASA-1800-II.

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3. F. Pasquill. "Atmospheric Diffusion A Study of the Dispersion of Windborne Material from Industrial and Other Sources," (New York, N. Y. : D. Van Nostrand Co , 1962).

4. G. P Cressman, "An Operational Objective Analysis System," Monthly Weather Review 87, 367 (1959).

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FORTRAN LISTINGS

FORTRAN listings for the subroutines are included on the following pages.

```
$IBFTC FALRA   LIST,DECK,M94/2
C      SUBROUTINE FALRAT
C      W.Y.G.ING            TECHNICAL OPERATIONS RESEARCH
C      DEC  14 1965
       SUBROUTINE  FALRAT(ALT,PSIZE,FV,ATEMP,RHO,FROG,ISOUT)
C
C***********************************************************************
C
C      SUBROUTINE FALRAT,USING DAVIE'S EQUATIONS, COMPUTES THE SETTLING
C      RATE OF PARTICLES BY USING PARTICLE DIAMETER (MICRONS), ALTITUDE
C      (METERS ABOVE MSL) AND A STANDARD ATMOSPHERE FOR WHICH THE DENSITY
C      AND VISCOSITY HAVE BEEN TABULATED IN ARRAYS RHO(I) AND ATEMP(I)
C      RESPECTIVELY.
C
C***********************************************************************
C
       DIMENSION ATEMP(260),RHO(260)
       REAL LOG10
C
C**********************     FALRAT GLOSSARY    *************************
C
C      ALT            HEIGHT OF THE PARTICLE ABOVE MSL   (METERS)
C      ATEMP(I)       DYNAMIC VISCOSITY OF AIR AT ((I-1)*200) METERS ABOVE
C                     MSL.                (KILOGRAM/METER-SECOND)
C      CDRR           THE DRAG COEFFICIENT * SQUARE OF THE REYNOLD-S
C                     NUMBER.
C      FROG           (4/3)*PARTICLE DENSITY*GRAVITY*(CUBIC METERS/ CUBIC
C                     MICRON).  KILOGRAM-METER/((SQR. SEC.)*(CUBIC MICRON))
C      FV             SETTLING RATE     (METERS/SEC)
C      PSIZE          PARTICLE DIAMETER     (MICRONS)
C      RHO(J)         ATM DENSITY AT (I-1)*200 METERS  ABOVE MSL.  (KILO-
C                     GRAMS/ CUBIC METER)
C
C***********************************************************************
C
 2     FORMAT(//38H DAVIES EQUATIONS ARE INACCURATE FOR  ,F12.3,12H MICRO
      1NS AT ,F12.3,7H METERS)
C
C **********************************************************************
C **********************************************************************
C
C      I IS THE INDEX (IN THE ARRAYS RHO(I) AND ATEMP(I)) THAT IDENTIFIES
C      THE 200 METER THICK LAYER CONTAINING THE PARTICLE.  THE ADDITION
C      OF 6.5 TO THE INDEX BEFORE TRUNCATION INSURES THAT PARTICLES
C      BETWEEN -100 AND +100 METERS ABOVE MSL WILL LIE IN THE SIXTH LAYER
C      WHICH HAS ITS CENTER LOCATED AT MSL, PARTICLES BETWEEN 100 AND 300
C      METERS ABOVE MSL WILL LIE IN THE  7-TH  LAYER WHICH HAS ITS CENTER
C      LOCATED AT 200 METERS ABOVE MSL, AND SO FORTH.
       I=(ALT/200.0)+6.5
       V0=PSIZE/ATEMP(I)
       V1=PSIZE*V0*FROG
       CDRR=V1*RHO(I)*V0
       IF(CDRR-140.0)100,100,150
 150   IF (CDRR-4.5E+7)200,151,151
C151   CDRR EXCEEDS THE UPPER RANGE OF DAVIE'S EQUATIONS.  HOWEVER, THE
C      NUMERICAL RESULT IS STILL USED.
 151   WRITE (ISOUT,2)PSIZE,ALT
       GO TO 200
C100   CDRR IS LESS THAN OR EQUAL TO 140.
 100   FV=V1*(41666.7 +CDRR*(-2.3363E+2+CDRR*(2.0154    -6.9105E-3*CDRR)))
       GO TO 300
```

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```
C200  CDRR IS GREATER THAN 140.                                              FALR  01
 200  QLOGA=ALOG10(CDRR)-20.775                                              FALR  02
      FV=50657.0 *V1*CDRR**((QLOGA*QLOGA-445.78)*0.0011255)                  FALR  03
C300  DRAG SLIP CORRECTED FALL RATE                                          FALR  04
 300  FV=FV*(1.0+2.55E-17/(PSIZE*RHO(I)))                                    FALR  05
 301  RETURN                                                                 FALR  06
      END                                                                    FALR  07
```

```
$IBFTC DUMP     LIST,DECK,M94/2                                         DUMP
      SUBROUTINE DUMPP                                                  DUMP    1
C        T.W.SCHWENKE  TECHNICAL OPERATIONS RESEARCH       SR  DUMPP DUMP    2
C     28 NOVEMBER 1966                                                  DUMP    3
C                                                                       DUMP    4
C***********************************************************************DUMP    5
C                                                                       DUMP    6
C     THIS SUBROUTINE SELECTS THE BEST SET OF PARTICLES TO DUMP,        DUMP    7
C     SORTS IT INTO THE LOW NUMBERED END OF THE PARTICLE ARRAYS, WRITES DUMP    8
C     IT OUT ONTO THE APPROPRIATE TAPE AND ADJUSTS PARTICLE SET COUNTERSDUMP    9
C     THE SET SELECTED FOR DUMPING IS THE GROUNDED PARTICLES SET WHEN-  DUMP   10
C     EVER DUMPING IT WOULD MAKE SUFFICIENT ROOM FOR THE INCOMING BLOCK DUMP   11
C     OF N PARTICLES.  IF THIS IS NOT THE CASE, THE LARGEST PARTICLE SETDUMP   12
C     IS SELECTED.                                                      DUMP   13
C                                                                       DUMP   14
C*********************** GLOSSARY  *************************************DUMP   15
C                                                                       DUMP   16
C     FOR ADDITIONAL GLOSSARY ENTRIES SEE SUBROUTINE LINK5              DUMP   17
C                                                                       DUMP   18
C     FMAST   SEE XPT                                                   DUMP   19
C     IC( )   THE CONTROL INTEGER ARRAY.    SEE LINK 5 GLOSSARY         DUMP   20
C     ICON    BLOCKING SORT MODE INDICATOR.  0=FIRST PASS, +=BOTTOM LOOPDUMP   21
C             ,-=TOP LOOP                                               DUMP   22
C     IOTOPO  THE OFF-TOPO MEMORY TAPE NUMBER                           DUMP   23
C     IOWIND  THE OUT-OF-WIND DATA MEMORY TAPE NUMBER                   DUMP   24
C     IPAROT  THE TIME LIMIT BOUNDARY MEMORY TAPE NUMBER                DUMP   25
C     IPOUT   THE TRANSPORT MODULE INTERMEDIATE OUTPUT TAPE NUMBER      DUMP   26
C     IRSET   A MARKER FOR THE BLOCKING SORT WHICH INDICATES BY THE     DUMP   27
C             VALUE  1  THAT THE TEMPORARY STORAGE LINE FOR A PARTICLE  DUMP   28
C             IS LOADED AND MUST BE EVENTUALLY UNLOADED                 DUMP   29
C     ISOUT   THE FORTRAN SYSTEM OUTPUT TAPE NUMBER                     DUMP   30
C     J       A GENERAL INDEX.    IN THE BLOCKING SORT, IT IS USED TO   DUMP   31
C             IDENTIFY THE PARTICLE THAT WAS JUST CLASSIFIED            DUMP   32
C     JB      BOTTOM LOOP INDEX FOR THE BLOCKING SORT                   DUMP   33
C     JBL     BLANK LINE INDEX FOR THE BLOCKING SORT                    DUMP   34
C     JFR     USED TO RECORD THE INDEX OF A FREE (BLANK) LINE IN THE    DUMP   35
C             BOTTOM PART OF THE PARTICLE ARRAY DURING THE CONSOLIDATIONDUMP   36
C             OF N BLANKS INTO THE TOP OF THE ARRAY                     DUMP   37
C     JT      TOP LOOP INDEX FOR THE BLOCKING SORT                      DUMP   38
C     JTEST   A TEMPORARY STORAGE THAT EVENTUALLY CONTAINS THE NUMBER   DUMP   39
C             OF PARTICLE DESCRIPTIONS IN THE CLASS TO BE DUMPED        DUMP   40
C     JTEST1  A TEMPORARY STORAGE WHICH EVENTUALLY CONTAINS THE NUMBER  DUMP   41
C             INDICATING THE KIND (CLASS) OF PARTICLE DESCRIPTION TO BE DUMP   42
C             DUMPED                                                    DUMP   43
C     N       THE NUMBER OF PARTICLES IN THE DATA BLOCK THAT IS WAITING DUMP   44
C             TO BE READ NEXT AT THE TIME WHEN DUMPP IS CALLED          DUMP   45
C     NALOFT  THE DIMENSIONED (MAXIMUM) SIZE OF THE PARTICLE ARRAY      DUMP   46
C     NBMAX   THE MAXIMUM NUMBER OF PARTICLE DESCRIPTIONS THAT CAN BE   DUMP   47
C             INCLUDED IN A SINGLE BLOCK AS WRITTEN ON ANY MEMORY OR    DUMP   48
C             INTERMEDIATE OUTPUT TAPE                                  DUMP   49
C     NFREE   THE NUMBER OF BLANK LINES (DENOTED BY FMAS( )=0) IN THE   DUMP   50
C             PARTICLE ARRAYS                                           DUMP   51
C     NG      A COUNT OF IN-CORE GROUNDED PARTICLES                     DUMP   52
C     NLOST   A COUNT OF THE PARTICLES IN THE PARTICLE ARRAY BUT LOCATEDDUMP   53
C             BEYOND THE COORDINATE LIMITS OF THE WIND OR TOPO DATA SETSDUMP   54
C     NTAP    A TEMPORARY STORAGE FOR THE NUMBER OF THE TAPE ONTO WHICH DUMP   55
C             THE DUMP IS TO BE MADE                                    DUMP   56
C     NTI     A COUNT OF IN-CORE PARTICLES THAT HAVE REACHED THE TIME   DUMP   57
C             BOUNDARY (ENDTIM)                                         DUMP   58
C     NTO     A COUNT OF IN-CORE PARTICLES BEYOND THE IN-CORE TOPO DATA DUMP   59
C     NW      A COUNT OF IN-CORE PARTICLES BEYOND THE IN-CORE WIND DATA DUMP   60
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C       N1         AN ASSIGNED GO TO BRANCH POINT FOR THE CLASSIFYING CODE    DUMP   61
C       N2         SEE N1                                                     DUMP   62
C       N3         SEE N1                                                     DUMP   63
C       N4         SEE N1                                                     DUMP   64
C       PST        SEE XPT                                                    DUMP   65
C       TPT        SEE XPT                                                    DUMP   66
C       XPT        TEMPORARY STORAGE FOR XP( ) SOMETIMES USED TO START A SORTDUMP   67
C       YPT        SEE XPT                                                    DUMP   68
C       ZPT        SEE XPT                                                    DUMP   69
C                                                                             DUMP   70
C*********************************************************************DUMP   71
C                                                                             DUMP   72
      COMMON /SET1/                                                           DUMP   73
     1          DIAM    ,DETID(12),IRISE   , IEXEC   , ISIN    , ISOUT     ,  DUMP   74
     2          SD      , SPAR    , SSAM    , TME     , TMP1    , TMP2      ,  DUMP   75
     3          T2M     , U       , VPR     , W       , X       , Z         ,  DUMP   76
     4          WHY(4 ), RMIN    , IDISTR  , SPAR1   , SPAR2   , SPAR3     ,  DUMP   77
     5          SPAR4   , SPAR5   , SPAR6   , SPAR7   , SPAR8   , SPAR9       DUMP   78
C                                                                             DUMP   79
C ********************************************************************DUMP   80
C                                                                             DUMP   81
      COMMON /SET2/                                                           DUMP   82
     1          S       , SUBSID  , GRINT   , BXLL    , BXLU    , BYLL        DUMP   83
     2,         BYLU    , TXLL    , TXLU    , TYLL    , TYLU    , XGZ         DUMP   84
     3,         YGZ     , NBLCK   , HTOPO   , TTOPO   , ILIM    , JLIM        DUMP   85
     4,         KLIM    , II      , JJ      , KK      , XP      , YP          DUMP   86
     5,         ZP      , FMAS    , TP      , PS      , VX      , VY          DUMP   87
     6,         VZ      , IL      , JL      , IBADD   , WGRINT  , NSTRAT      DUMP   88
     7,         WLLX    , WLLY    , WURX    , WURY    , BOTHIT  , IPARIN      DUMP   89
     8,         IOTOPO  , IOWIND  , IHTOPO  , IPOUT   , IPAROT  , JTOP1       DUMP   90
     9,         JWIND1  , IRROR   , TLIMIT  , ENDTIM  , IC      , IBYPAS      DUMP   91
     1,         JTOPJ   , NLOST   , N3      , NTO     , NTI     , NW          DUMP   92
     2,         NALOFT  , JTIME1  , NBMAX   , NFREE   , N       , NCL         DUMP   93
     3,         CRMAXY  , CRUHT   , NCRTYP  , BZ      , CRMINX  , CRMINY      DUMP   94
     4,         UO      , SN      , CS      , NLOCIR  , DTLOC   , ATEMP       DUMP   95
     5,         RHO     , NA      , TGZ     , DTMAC   , FROG    , CRMAXX      DUMP   96
     6,         ROPART                                                        DUMP   97
      DIMENSION TOPOLM(4,4)    ,NINTAR(4)       ,ITOPLM(3,4)                  DUMP   98
      DIMENSION S(1 ,10)       ,SUBSID(400)     ,IC(18)                       DUMP   99
      DIMENSION XP(200)        ,YP(200)         ,ZP(200)       ,FMAS(200)     DUMP  100
      DIMENSION TP(200)        ,PS(200)         ,ATEMP(260)    ,RHO(260)      DUMP  101
      DIMENSION VX(1500)       ,VY(1500)        ,VZ(1500)      ,IL(70)        DUMP  102
      DIMENSION JL(70)         ,IBADD(70)       ,WURX(70)                     DUMP  103
      DIMENSION WGRINT(70)                      ,WLLX(70)      ,WLLY(70)      DUMP  104
      DIMENSION WURY(70)       ,BOTHIT(70)      ,SN(6)         ,CS(6)         DUMP  105
      DIMENSION CRMINX(6)      ,CRMAXX(6)       ,CRMINY(6)     ,CRMAXY(6)     DUMP  106
      DIMENSION CRUHT(6)       ,NCRTYP(6)       ,UO(6)                        DUMP  107
C                                                                             DUMP  108
C*********************************************************************DUMP  109
C                                                                             DUMP  110
 1    FORMAT(1H1,4XI7,15H LOST PARTICLES)                                     DUMP  111
 2    FORMAT(/6X,2HXP,10X2HYP,10X,2HZP,10X,2HTP,10X,2HPS,8X,4HFMAS)           DUMP  112
 3    FORMAT(1X,6E12.5)                                                       DUMP  113
 4    FORMAT(10I5)                                                            DUMP  114
 6    FORMAT(5X11HBEYOND TOPO)                                                DUMP  115
 7    FORMAT(5X13HTIME BOUNDARY)                                              DUMP  116
 8    FORMAT(5X11HBEYOND WIND)                                                DUMP  117
 9    FORMAT(5X8HGROUNDED)                                                    DUMP  118
```

```
C
C ********************************************************************
C
      DATA PROGRM/6H DUMPP/
C
C*********************************************************************
C*********************************************************************
C
C     MUST ANY PARTICLES BE DUMPED TO MAKE ROOM FOR THE INCOMING BLOCK
C     OF N PARTICLES OR TO CLEAR THE PARTICLE ARRAYS.  YES TO 151
      IF(N-NFREE)150,150,151
 150  JTEST=0
      GO TO 152
C
C 151 WOULD DUMPING THE GROUNDED PARTICLES PROVIDE SUFFICIENT ROOM FOR
C     THE BLOCK OF N INCOMING PARTICLE DESCRIPTIONS.  YES TO 1512
 151  IF(NFREE+NG-N)1511,1512,1512
C
C 1512 PREPARE TO DUMP THE GROUNDED PARTICLE DESCRIPTIONS
 1512 JTEST1=1
      JTEST=NG
      GO TO 18
C1511 DETERMINE WHICH SET OF PARTICLES TO DUMP
C     FIND THE IDENTIFIER (JTEST1) AND SIZE (JTEST) OF THE MOST
C     NUMEROUS CLASS OF PARTICLES IN THE PARTICLE ARRAYS
 1511 IF(NLOST-NG)10,11,11
 10   JTEST=NG
      JTEST1=1
      GO TO 12
 11   JTEST=NLOST
      JTEST1=2
 12   IF(JTEST-NTO)13,14,14
 13   JTEST=NTO
      JTEST1=3
 14   IF(JTEST-NTI)15,16,16
 15   JTEST1=4
      JTEST=NTI
 16   IF(JTEST-NW)17,18,18
 17   JTEST1=5
      JTEST=NW
C 18  AT THIS POINT JTEST HAS MAX(NG,NLOST,NTO,NTI,NW).
C     JTEST1 INDICATES THE KIND OF PARTICLE DESCRIPTION TO BE DUMPED
C     SEE THE FOLLOWING CODE EXPLANATION FOR JTEST1=1 THRU 5
C
C     JTEST1   NAME OF          KIND OF PARTICLE DESCRIPTIONS
C     VALUE    CLASS COUNTER    TO BE DUMPED ONTO TAPE
C      1           NG             GROUNDED PARTICLES
C      2           NLOST          PARTICLES BEYOND THE AREAS FOR WHICH
C                                 BOTH TOPO AND WINDS HAVE BEEN SPEC-
C                                 IFIED
C      3           NTO            PARTICLES BEYOND THE LIMITS OF THE
C                                 TOPO DATA CURRENTLY AVAILABLE IN CORE
C      4           NTI            PARTICLES THAT CANNOT BE VALIDLY
C                                 TRANSPORTED FURTHER UNTIL THE WIND
C                                 FIELD DESCRIPTION IS UPDATED
C      5           NW             PARTICLES BEYOND THE LIMITS OF THE
C                                 WIND DATA CURRENTLY AVAILABLE IN CORE
C
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C     TEST TO SEE THAT JTEST HAS AN ACCEPTABLE VALUE.   UNACCEPTABLE TO DUMP 177
C     ERROR STOP AT 184                                                 DUMP 178
C                                                                       DUMP 179
 18   IF(JTEST)184,184,182                                              DUMP 180
 184  IRROR= 184                                                        DUMP 181
 7734 CALL ERROR(PROGRM,IRROR,ISOUT)                                    DUMP 182
      GO TO 60                                                          DUMP 183
C                                                                       DUMP 184
C 182 IS THE SIZE (JTEST) OF THE SELECTED CLASS GREATER THAN THE MAXIMUMDUMP 185
C     ALLOWABLE OUTPUT BLOCK SIZE (NBMAX)).  YES TO 183.                DUMP 186
 182  IF(JTEST-NBMAX)181,181,183                                        DUMP 187
C                                                                       DUMP 188
C 183 RESET JTEST EQUAL TO THE MAXIMUM ALLOWABLE BLOCK SIZE SO THAT AN  DUMP 189
C     ACCEPTABLE BLOCK SIZE WILL BE DUMPED.                             DUMP 190
 183  JTEST=NBMAX                                                       DUMP 191
C                                                                       DUMP 192
C 181 MAKE ASSIGNMENTS FOR THE EFFICIENT CONTROL OF THE CODE THAT WILL  DUMP 193
C     LATER BE USED TO CLASSIFY PARTICLE DESCRIPTIONS AS TO WHETHER     DUMP 194
C     THEY ARE TO BE DUMPED, NOT TO BE DUMPED, OR MERELY BLANK.  ALSO   DUMP 195
C     DECREASE THE APPROPRIATE CLASS COUNTER BY THE NUMBER OF DESCRIP-  DUMP 196
C     TIONS ABOUT TO BE DUMPED (JTEST) AND MAKE AN APPROPRIATE SETTING  DUMP 197
C     OF THE OUTPUT TAPE NAME NTAP.                                     DUMP 198
C 181 GO TO THE APPROPRIATE SELECTION CODE                              DUMP 199
 181  GO TO (19,20,21,22,23),JTEST1                                     DUMP 200
C                                                                       DUMP 201
C 19  CODE TO MAKE ASSIGNMENTS FOR THE SELECTION OF GROUNDED PARTICLES. DUMP 202
C     GROUNDED PAR ICLES ARE IDENTIFIED BY THE PATTERN  -,-  IN THE     DUMP 203
C     SIGNS OF FMAS( ) AND TP( ) UNDER THE CONDITION THAT TP( )+TLIMIT  DUMP 204
C     DOES NOT EQUAL ZERO.                                              DUMP 205
C     DESCRIPTIONS OF GROUNDED PARTICLES ARE ALWAYS WRITTEN ONTO THE    DUMP 206
C     TRANSPORT INTERMEDIATE OUTPUT TAPE IPOUT                          DUMP 207
 19   NG=NG-JTEST                                                       DUMP 208
      NTAP=IPOUT                                                        DUMP 209
      ASSIGN 300 TO N1                                                  DUMP 210
      ASSIGN 400 TO N3                                                  DUMP 211
      ASSIGN 42 TO N2                                                   DUMP 212
      ASSIGN 42 TO N4                                                   DUMP 213
      GO TO 99                                                          DUMP 214
C                                                                       DUMP 215
C 20  CODE TO MAKE ASSIGNMENTS FOR THE SELECTION OF PARTICLES THAT ARE  DUMP 216
C     LOST TO THE INVESTIGATION.    THESE PARTICLES ARE IDENTIFIED BY A DUMP 217
C     NEGATIVE FMAS( ) AND A TP( ) WHICH EQUALS TLIMIT, THE TIME WHEN   DUMP 218
C     THE TRANSPORT OF PARTICLES IS TO CEASE.  LOST PARTICLES ARE MERELYDUMP 219
C     WRITTEN ONTO THE SYSTEM OUTPUT TAPE TO INFORM THE RESEARCHER OF   DUMP 220
C     THEIR REMOVAL FROM THE TRANSPORT.                                 DUMP 221
 20   NLOST=NLOST-JTEST                                                 DUMP 222
      NTAP=ISOUT                                                        DUMP 223
      ASSIGN 500 TO N1                                                  DUMP 224
      ASSIGN 42 TO N2                                                   DUMP 225
      GO TO 99                                                          DUMP 226
C                                                                       DUMP 227
C 21  CODE TO MAKE ASSIGNMENTS FOR THE SELECTION OF PARTICLES THAT HAVE DUMP 228
C     GONE BEYOND THE IN-CORE TOPOGRAPHY.  THESE PARTICLES ARE IDENTI-  DUMP 229
C     FIED BY A POSITIVE FMAS( ) AND A NEGATIVE TP( ).  THEY ARE        DUMP 230
C     WRITTEN ONTO THE OFF-TOPO TAPE (IOTOPO) BUT IF USE OF IOTOPO HAS  DUMP 231
C     BEEN SUPPRESSED (BY SETTING IC(2)=1),THEY ARE WRITTEN ONTO THE    DUMP 232
C     SYSTEM OUTPUT TAPE INSTEAD.  THIS IS TO LET THE RESEARCHER KNOW   DUMP 233
C     THAT HIS SUPPRESSION OF IOTOPO HAS LED TO A LOSS OF PARTICLES FROMDUMP 234
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C     THE TRANSPORT PROCESS.                                            DUMP 235
 21   IF(IC(2)-1)211,212,211                                            DUMP 236
 212  NTAP=ISOUT                                                        DUMP 237
      GO TO 213                                                         DUMP 238
C 211 JTOP1=1 INDICATES THAT THE ONLY OFF-TOPO PARTICLES THAT REMAIN IN DUMP 239
C     THE TRANSPORT ARE THOSE THAT ARE IN CORE IN THE PARTICLE ARRAYS.  DUMP 240
C                                                                       DUMP 241
 211  JTOP1=1                                                           DUMP 242
      NTAP=IOTOPO                                                       DUMP 243
 213  NTO=NTO-JTEST                                                     DUMP 244
      ASSIGN 300 TO N2                                                  DUMP 245
      ASSIGN 100 TO N3                                                  DUMP 246
      ASSIGN 42 TO N4                                                   DUMP 247
      ASSIGN 42 TO N1                                                   DUMP 248
      GO TO 99                                                          DUMP 249
C                                                                       DUMP 250
C 22  CODE TO MAKE ASSIGNMENTS FOR THE SELECTION OF PARTICLES THAT CAN  DUMP 251
C     NOT BE TRANSPORTED FURTHER UNTIL THE WIND FIELD IS UPDATED.  THESEDUMP 252
C     PARTICLES ARE IDENTIFIED BY A POSITIVE FMAS( ) AND A IP( ) EQUAL  DUMP 253
C     TO ENDTIM.  NORMALLY THEY ARE WRITTEN ON TAPE IPAROT,BUT WHEN THE DUMP 254
C     USER HAS SET IC(4)=1 TO SUPPRESS IPAROT, THEY ARE WRITTEN ON THE  DUMP 255
C     SYSTEM OUTPUT TAPE TO NOTIFY THE USER.                            DUMP 256
 22   IF(IC(4)-1)221,222,221                                            DUMP 257
 222  NTAP=ISOUT                                                        DUMP 258
      GO TO 223                                                         DUMP 259
C                                                                       DUMP 260
C 221 JTIME1=1 INDICATES THAT THE ONLY OUT-OF-WIND PARTICLES THAT REMAINDUMP 261
C     IN THE TRANSPORT ARE THOSE THAT ARE IN THE PARTICLE ARRAYS.       DUMP 262
 221  JTIME1=1                                                          DUMP 263
      NTAP=IPAROT                                                       DUMP 264
 223  NTI=NTI-JTEST                                                     DUMP 265
      ASSIGN 600 TO N2                                                  DUMP 266
      ASSIGN 42 TO N1                                                   DUMP 267
      GO TO 99                                                          DUMP 268
C                                                                       DUMP 269
C 23  CODE TO MAKE ASSIGNMENTS FOR THE SELECTION OF PARTICLES THAT ARE  DUMP 270
C     BEYOND THE LIMITS OF THE WIND DATA CURRENTLY AVAILABLE IN CORE.   DUMP 271
C     THESE PARTICLES ARE IDENTIFIED BY A NEGATIVE FMAS( ) AND  POSITIVEDUMP 272
C     IP( ).  NORMALLY THEY ARE WRITTEN ONTO TAPE IOWIND, BUT WHEN THE  DUMP 273
C     USER HAS SET IC(3)=1 TO SUPPRESS IOWIND, THEY ARE WRITTEN ON THE  DUMP 274
C     SYSTEM OUTPUT TAPE TO NOTIFY THE USER.                            DUMP 275
 23   IF(IC(3)-1)231,232,231                                            DUMP 276
 232  NTAP=ISOUT                                                        DUMP 277
      GO TO 233                                                         DUMP 278
C                                                                       DUMP 279
C 231 JWIND1=1 INDICATES THAT THE ONLY OUT-OF-WIND-FIELD PARTICLES THAT DUMP 280
C     REMAIN IN THE TRANSPORT ARE THOSE THAT ARE IN THE PARTICLE ARRAYS.DUMP 281
 231  JWIND1=1                                                          DUMP 282
      NTAP=IOWIND                                                       DUMP 283
 233  NW=NW-JTEST                                                       DUMP 284
      ASSIGN 300 TO N1                                                  DUMP 285
      ASSIGN 100 TO N4                                                  DUMP 286
      ASSIGN 42 TO N2                                                   DUMP 287
      ASSIGN 42 TO N3                                                   DUMP 288
C                                                                       DUMP 289
C 99  INITIALIZE FOR BLOCKING SORT                                      DUMP 290
 99   IRSET=0                                                           DUMP 291
      ICON=0                                                            DUMP 292
      JB=NALOFT                                                         DUMP 293
      JT=1                                                              DUMP 294
      J=JB                                                              DUMP 295
C                                                                       DUMP 296
C     WRITE OUT A DUMP SUMMARY                                          DUMP 297
      WRITE (ISOUT,4)JTEST,JTEST1,NFREE,NG,NLOST,NTO,NTI,NW             DUMP 298
C     NOW BEGIN THE BLOCKING SORT                                       DUMP 299
C 98  CLASSIFY THE JTH PARTICLE AS BLANK, TO BE DUMPED, OR NOT TO BE    DUMP 300
C     DUMPED                                                            DUMP 301
 98   IF(FMAS(J))30,31,32                                               DUMP 302
 30   GO TO N1,(300,500,42)                                             DUMP 303
 32   GO TO N2,(42,300,500,600)                                         DUMP 304
 300  IF(TP(J))33,35,35                                                 DUMP 305
 33   GO TO N3,(400,100,42)                                             DUMP 306
 35   GO TO N4,(42,100)                                                 DUMP 307
 400  IF(TP(J)+ENDTIM)100,42,100                                        DUMP 308
 500  IF(TP(J)-TLIMIT) 42,100,42                                        DUMP 309
 600  IF(TP(J)-ENDTIM)42,100,100                                        DUMP 310
C                                                                       DUMP 311
C 31   BLANK     NOT TO BE DUMPED                                       DUMP 312
 31   IF(ICON)422,901,424                                               DUMP 313
C 42   NON-BLANK    NOT TO BE DUMPED                                    DUMP 314
 42   IF(ICON)421,424,424                                               DUMP 315
C 100       TO BE DUMPED                                                DUMP 316
 100  IF(ICON)903,904,900                                               DUMP 317
C                                                                       DUMP 318
C     ICON=0     FIRST PASS                                             DUMP 319
C     ICON=+1     BOTTOM LOOP                                           DUMP 320
C     ICON=-1    TOP LOOP                                               DUMP 321
C                                                                       DUMP 322
C 900 MOVE THE JB-TH LINE TO THE BLANK LINE (JBL)                       DUMP 323
 900  XP(JBL)=XP(JB)                                                    DUMP 324
      YP(JBL)=YP(JB)                                                    DUMP 325
      ZP(JBL)=ZP(JB)                                                    DUMP 326
      TP(JBL)=TP(JB)                                                    DUMP 327
      PS(JBL)=PS(JB)                                                    DUMP 328
      FMAS(JBL)=FMAS(JB)                                                DUMP 329
      JT=JT+1                                                           DUMP 330
      FMAS(JB)=0.0                                                      DUMP 331
      IF(JT-JTEST)901,901,1103                                          DUMP 332
 901  JBL=JB                                                            DUMP 333
      ICON=-1                                                           DUMP 334
      J=JT                                                              DUMP 335
 902  JB=JB-1                                                           DUMP 336
      GO TO 98                                                          DUMP 337
C 904 STORE THE JB-TH PARTICLE IN TEMPORARY STORAGE AND SET IRSET=1 TO  DUMP 338
C     INDICATE THAT IT MUST BE PUT BACK INTO THE PARTICLE ARRAYS AT THE DUMP 339
C     END OF THIS DUMP OPERATION.                                       DUMP 340
 904  XPT=XP(JB)                                                        DUMP 341
      YPT=YP(JB)                                                        DUMP 342
      ZPT=ZP(JB)                                                        DUMP 343
      TPT=TP(JB)                                                        DUMP 344
      PST=PS(JB)                                                        DUMP 345
      FMAST=FMAS(JB)                                                    DUMP 346
      IRSET= 1                                                          DUMP 347
      FMAS(JB)=0.0                                                      DUMP 348
      GO TO 901                                                         DUMP 349
 903  JT=JT+1                                                           DUMP 350
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      J=JT                                                              DUMP 351
      IF(JT-JTEST)98,98,110                                             DUMP 352
 424  J=J-1                                                             DUMP 353
      JB=JB-1                                                           DUMP 354
      GO TO 1104                                                        DUMP 355
C                                                                       DUMP 356
C 421 MOVE THE JT-TH LINE TO THE BLANK LINE (JBL)                       DUMP 357
 421  XP(JBL)=XP(JT)                                                    DUMP 358
      YP(JBL)=YP(JT)                                                    DUMP 359
      ZP(JBL)=ZP(JT)                                                    DUMP 360
      TP(JBL)=TP(JT)                                                    DUMP 361
      PS(JBL)=PS(JT)                                                    DUMP 362
      FMAS(JBL)=FMAS(JT)                                                DUMP 363
 422  JBL=JT                                                            DUMP 364
 423  ICON=1                                                            DUMP 365
      J=JB                                                              DUMP 366
 1104 IF( JB-JTEST)110,110,98                                           DUMP 367
 1103 JBL = JB                                                          DUMP 368
C 110 IS THE TEMPORARY STORAGE LOADED.    YES TO 1101                   DUMP 369
 110  IF(IRSET)1101,1102,1101                                           DUMP 370
C                                                                       DUMP 371
C 1101 REPLACE THE TEMPORARILY STORED PARTICLE IN THE BLANK LINE (JBL)  DUMP 372
 1101 XP(JBL) = XPT                                                     DUMP 373
      YP(JBL) = YPT                                                     DUMP 374
      ZP(JBL) = ZPT                                                     DUMP 375
      TP(JBL) = TPT                                                     DUMP 376
      PS(JBL) = PST                                                     DUMP 377
      FMAS(JBL)=FMAST                                                   DUMP 378
 1102 CONTINUE                                                          DUMP 379
C                                                                       DUMP 380
C     RESET KEYS OF PARTICLES BEING DUMPED JUST BEFORE PRINTING OR      DUMP 381
C     DUMPING THEM                                                      DUMP 382
      DO 131 J=1,JTEST                                                  DUMP 383
      IF(FMAS(J))101,111,111                                            DUMP 384
 101  FMAS(J)=-FMAS(J)                                                  DUMP 385
 111  IF(TP(J))121,131,131                                              DUMP 386
 121  TP(J)=-TP(J)                                                      DUMP 387
 131  CONTINUE                                                          DUMP 388
C                                                                       DUMP 389
C                                                                       DUMP 390
C                                                                       DUMP 391
C     NOW DUMP THE SELECTED DESCRIPTIONS                                DUMP 392
C 50  IF THE SYSTEM OUTPUT TAPE IS TO BE WRITTEN, FIRST SELECT AND      DUMP 393
C     WRITE AN APPROPRIATE TITLE.                                       DUMP 394
 50   IF(NTAP-ISOUT)52,51,52                                            DUMP 395
C                                                                       DUMP 396
C     IF THE PRINTING OF LOST PARTICLE DESCRIPTIONS IS TO BE SUPRESSED, DUMP 397
C     GO TO 54                                                          DUMP 398
 51   IF(IC(8).NE.0) GO TO 54                                           DUMP 399
      WRITE (ISOUT,1)JTEST                                              DUMP 400
      WRITE (ISOUT,2)                                                   DUMP 401
      GO TO (511,516,513,514,515),JTESTT                                DUMP 402
 511  WRITE (ISOUT,9)                                                   DUMP 403
      GO TO 516                                                         DUMP 404
 513  WRITE (ISOUT,6)                                                   DUMP 405
      GO TO 516                                                         DUMP 406
 514  WRITE (ISOUT,7)                                                   DUMP 407
      GO TO 516                                                         DUMP 408
 515   WRITE (ISOUT,8)                                                   DUMP 409
 516   WRITE (ISOUT,3)(XP(J),YP(J),ZP(J),TP(J),PS(J),FMAS(J),J=1,JTEST)  DUMP 410
       GO TO 54                                                          DUMP 411
 52    WRITE (NTAP)JTEST                                                 DUMP 412
       IF(NTAP-IPOUT)252,155,252                                         DUMP 413
 155   WRITE (NTAP)(XP(J),YP(J), TP(J),PS(J),FMAS(J),J=1,JTEST)          DUMP 414
       GO TO 54                                                          DUMP 415
 252   WRITE (NTAP)(XP(J),YP(J),ZP(J),TP(J),PS(J),FMAS(J),J=1,JTEST)     DUMP 416
       IF(IC(6)-1)54,2521,2521                                           DUMP 417
 2521  WRITE (ISOUT,3)(XP(J),YP(J),ZP(J),TP(J),PS(J),FMAS(J),J=1,JTEST)  DUMP 418
C                                                                        DUMP 419
C 54   ADD THE NUMBER OF LINES JUST DUMPED TO THE NUMBER OF LINES EMPTY  DUMP 420
C      PREVIOUSLY AND THEN ZERO OUT THE IDP OF THE LINES JUST DUMPED TO  DUMP 421
C      AVOID DOUBLE COUNTING                                             DUMP 422
 54    NFREE=NFREE+JTEST                                                 DUMP 423
       DO 541 J=1,JTEST                                                  DUMP 424
 541   FMAS(J)=0.0                                                       DUMP 425
C                                                                        DUMP 426
       IF(NFREE-N)151,152,152                                            DUMP 427
C                                                                        DUMP 428
C 152  ARE THERE NOW ENOUGH CONTIGUOUS BLANK LINES IN THE TOP OF THE     DUMP 429
C      PARTICLE ARRAY TO RECIEVE THE N PARTICLES THAT ARE WAITING TO BE  DUMP 430
C      READ IN.  YES TO 60                                               DUMP 431
 152   IF(N-JTEST)60,60,154                                              DUMP 432
C                                                                        DUMP 433
C 154  CONSOLIDATE N BLANK LINES INTO THE TOP OF THE PARTICLE ARRAY      DUMP 434
 154   JFR=NALOFT+1                                                      DUMP 435
       K=JTEST+1                                                         DUMP 436
       DO 56 J=K,N                                                       DUMP 437
       IF(FMAS(J))57,56,57                                               DUMP 438
C 57   A PARTICLE MUST BE MOVED DOWN                                     DUMP 439
 57    JFR=JFR-1                                                         DUMP 440
       IF(FMAS(JFR))58,59,58                                             DUMP 441
 58    IF(JFR-JTEST)60,60,57                                             DUMP 442
C 59   MOVE THE PARTICLE                                                 DUMP 443
 59    XP(JFR)=XP(J)                                                     DUMP 444
       YP(JFR)=YP(J)                                                     DUMP 445
       ZP(JFR)=ZP(J)                                                     DUMP 446
       TP(JFR)=TP(J)                                                     DUMP 447
       PS(JFR)=PS(J)                                                     DUMP 448
       FMAS(JFR)=FMAS(J)                                                 DUMP 449
       FMAS(J)=0.0                                                       DUMP 450
 56    CONTINUE                                                          DUMP 451
 60    RETURN                                                            DUMP 452
       END                                                               DUMP 453
                                                                              454*

                                                                              454 *
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$IBFTC RDTOP    LIST,DECK,M94/2                                         RDTO
      SUBROUTINE RDTOPO (LB)                                            RDTO
C     11 OCT 66                                                         RDTO
C     T. W. SCHWENKE   TECHNICAL OPERATIONS RESEARCH    SR  OUTPRO CHAINRDTO
C     THIS SUBROUTINE MERELY READS ONE TOPO BLOCK INTO ARRAYS S AND     RDTO
C     SUBSID. IT EXPECTS READ LIMITS TO BE IN COMMON WORDS II,JJ,KK.    RDTO
C     ERROR EXIT IF BAD LIMITS                                          RDTO
C                                                                       RDTO
C *********************************************************************RDTO
C                                                                       RDTO
      COMMON /SET1/                                                     RDTO
     1          DIAM   , DETID  , IRISE  , IEXEC  , ISIN   , ISOUT   ,  RDTO
     2          SD     , SPAR   , SSAM   , TME    , TMP1   , TMP2    ,  RDTO
     3          T2M    , C      , VPR    , W      , X      , Z       ,  RDTO
     4          WHY    , RMIN   , IDISTR , SPAR1  , SPAR2  , SPAR3   ,  RDTO
     5          SPAR4  , SPAR5  , SPAR6  , SPAR7  , SPAR8  , SPAR9      RDTO
      DIMENSION  DETID(12),WHY(40)                                      RDTO
C                                                                       RDTO
C *********************************************************************RDTO
C                                                                       RDTO
      COMMON /SET2/                                                     RDTO
     1          S      , SUBSID , GRINT  , BXLL   , BXLU   , BYLL       RDTO
     2,         BYLU   , TXLL   , TXLU   , TYLL   , TYLU   , XGZ        RDTO
     3,         YGZ    , NBLCK  , HTOPO  , TTOPO  , ILIM   , JLIM       RDTO
     4,         KLIM   , II     , JJ     , KK     , XP     , YP         RDTO
     5,         ZP     , FMAS   , TP     , PS     , VX     , VY         RDTO
     6,         VZ     , IL     , JL     , IBADD  , WGRINT , NSTRAT     RDTO
     7,         WLLX   , WLLY   , WORX   , WORY   , BOTHIT , IPARIN     RDTO
     8,         IOTOPO , IOWIND , IHTOPO , IPOUT  , IPAROT , JTOP1      RDTO
     9,         JWIND1 , IRROR  , TLIMIT , ENDTIM , IC     , IBYPAS     RDTO
     1,         JTOPO  , NLOST  , NG     , NTO    , NTI    , NW         RDTO
     2,         NALOFT , JTIME1 , NBMAX  , NFREE  , N      , NCL        RDTO
     3,         CRMAXY , CROMT  , NCRTYP , BZ     , CRMINX , CRMINY     RDTO
     4,         UU     , SN     , CS     , NLOCIR , DTLOC  , ATEMP      RDTO
     5,         RHO    , NA     , TGZ    , DTMAC  , FROG   , CRMAXX     RDTO
     6,         ROPART                                                  RDTO
      DIMENSION TOPOLM(4,4)   ,NINTAR(4)      ,ITOPLM(3,4)              RDTO
      DIMENSION S(1 ,10)      ,SUBSID(400)    ,IC(18)                   RDTO
      DIMENSION XP(200)       ,YP(200)        ,ZP(200)      ,FMAS(200)  RDTO
      DIMENSION TP(200)       ,PS(200)        ,ATEMP(260)   ,RHO(260)   RDTO
      DIMENSION VX(1500)      ,VY(1500)       ,VZ(1500)     ,IL(70)     RDTO
      DIMENSION JL(70)        ,IBADD(70)      ,WORX(70)                 RDTO
      DIMENSION WGRINT(70)                    ,WLLX(70)     ,WLLY(70)   RDTO
      DIMENSION WORY(70)      ,BOTHIT(70)     ,SN(6)        ,CS(6)      RDTO
      DIMENSION CRMINX(6)     ,CRMAXX(6)      ,CRMINY(6)    ,CRMAXY(6)  RDTO
      DIMENSION CROMT(6)      ,NCRTYP(6)      ,UU(6)                    RDTO
C                                                                       RDTO
C *********************************************************************RDTO
C                                                                       RDTO
 9    FORMAT(33HOTOPO DATA TOO LARGE FOR PROGRAM.)                      RDTO
 11   FORMAT(35HO INCORRECT TOPO TABLE OF CONTENTS.)                    RDTO
 100  FORMAT(10F10.3)                                                   RDTO
C                                                                       RDTO
C                                                                       RDTO
C *********************************************************************RDTO
C *********************************************************************RDTO
C                                                                       RDTO
      II=ITOPLM(1,LB)                                                   RDTO
      JJ=ITOPLM(2,LB)                                                   RDTO
      KK=ITOPLM(3,LB)                                                   RDTO
      TTOPO=TOPOLM(4,LB)                                                RDTO
      BXLL=TOPOLM(1,LB)
      BXLU=TOPOLM(3,LB)*FLOAT(II)+BXLL
      BYLL=TOPOLM(2,LB)
      BYLU=TOPOLM(3,LB)*FLOAT(JJ)+BYLL
      JFTOPO=LB+1
      IF(II)1,1,2
2     IF(JJ)1,1,3
3     IF(KK)1,4,4
4     IF(II-ILIM)5,5,6
5     IF(JJ-JLIM)7,7,6
7     IF(KK-KLIM)8,8,6
6     WRITE (ISOUT,9)
10    STOP
1     WRITE (ISOUT,11)
      GO TO 10
8     READ (IHTOPO)((S(I,J),I=1,II),J=1,JJ)
      READ (IHTOPO)(SUBSID(K),K=1,KK)
      WRITE (ISOUT,100)(SUBSID(K),K=1,KK)
      RETURN
      END
```

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$IBFTC LNK5     LIST,DECK,M94/2                                         LNK5
      SUBROUTINE LINK5                                                  LNK5
C           T.W.SCHWENKE  TECHNICAL OPERATIONS RESEARCH          LINK 5 LNK5
C    15 OCTOBER 1966                                                    LNK5
C     FIRST OVERLAY LINK OF TRANSPORT PROGRAM. INITIALIZATION AND CALL  LNK5
C      OF WIND FIELD PREPARING SUBROUTINE  MKWIND                       LNK5
C                                                                       LNK5
C ***********************************************************************LNK5
C                                                                       LNK5
C************        TAPE IDENTIFICATIONS AND ASSIGNMENTS     ********** LNK5
C                                                                       LNK5
C        NAME                 CONTENT                                   LNK5
C                                                                       LNK5
C       IHTOPO              TOPOGRAPHIC HEIGHT DATA TAPE                LNK5
C       IOTOPO              PARTICLES ALOFT BUT BEYOND IN-CORE TOPOGRAPHY  LNK5
C       IOWIND              PARTICLES ALOFT BUT BEYOND IN CORE WIND FIELD  LNK5
C       IPARIN              PARTICLES ALOFT AND TO BE PROCESSED         LNK5
C       IPAROT              PARTICLES ALOFT AWAITING NEXT TIME PERIOD WINDS LNK5
C       IPOUT               PROGRAM SPECIFIC OUTPUT                     LNK5
C       ISOUT               SYSTEM (BCD) OUTPUT TAPE                    LNK5
C       ISIN                SYSTEM INPUT TAPE                           LNK5
C                                                                       LNK5
C************       PROGRAM GLOSSARY      ***********                   LNK5
C                                                                       LNK5
C       ATEMP(J)              ATMOSPHERIC VISCOSITY IN THE J-TH STRATUM LNK5
C       AX,AY,AZ              OUTPUT ARGUMENTS OF LOCAL CIRCULATION SYSTEM  LNK5
C                             CODES.  X,Y,AND Z COMPONENTS OF WIND AT THE   LNK5
C                             POSITION OF THE J-TH PARTICLE.            LNK5
C       BLANK                 BLANK LITERAL  (      )                   LNK5
C       BOTHIT(K)             ALTITIDE OF BOTTOM OF KTH WIND DATA BLOCK LNK5
C       BZ                    LENGTH OF THE SIDE OF THE SQUARE CLOUD SUBDIVIS-LNK5
C                             IONS AT THE TIME OF THEIR DEFINITION      LNK5
C       CBREZ1                SUBROUTINE    SEA BREEZE CIRCULATION MODEL  LNK5
C       CIRMIN                TIME UNTIL INTERSECTION WITH THE FIRST LOCAL  LNK5
C                             WIND SYSTEM                               LNK5
C       CIRTYP(J)             THE LOCAL CIRCULATION TYPE OF THE JTH SYSTEM  LNK5
C                1        MOUNTAIN WIND 1                               LNK5
C                2        RIDGE WIND 1                                  LNK5
C                3        SEA BREEZE 1                                  LNK5
C                4        SEA BREEZE 2                                  LNK5
C                5            NOT ASSIGNED                              LNK5
C       CRID( )               CLOUD RISE IDENTIFICATION                 LNK5
C       CRMINX(J)             SMALLEST X COORDINATE OF THE JTH LOCAL SYSTEM  LNK5
C       CRMAXX(J)             LARGEST  X COORDINATE OF THE JTH LOCAL SYSTEM  LNK5
C       CRMINY(J)             SMALLEST Y COORDINATE OF THE JTH LOCAL SYSTEM  LNK5
C       CRMAXY(J)             LARGEST  Y COORDINATE OF THE JTH LOCAL SYSTEM  LNK5
C       CROHT(K)          HEIGHT OF TOP SURFACE OF THE KTH LOCAL CIRCULATION  LNK5
C                         SYSTEM CELL.                                  LNK5
C       DETID(J)              INITIAL CONDITIONS (FIREBALL) IDENTIFICATION  LNK5
C       DENTI                 TOPOGRAPHY TAPE IDENTIFICATION LITERAL (IHTOPO) LNK5
C                             AS READ FROM TAPE                         LNK5
C       DENTT                 PARTICLES ALOFT INPUT TAPE IDENTIFICATION LNK5
C                             LITERAL AS READ FROM TAPE                 LNK5
C       DTLOC                 TIME INCREMENT FOR USE IN TRANSPORT WITHIN LOCALLNK5
C                             CIRCULATION SYSTEM CELLS                  LNK5
C       DTMAC                 TIME INCREMENT FOR USE IN TRANSPORT WITHIN THE  LNK5
C                             MACRO FIELD BUT BELOW MAXIMUM TOPOGRAPHIC HEIGHTLNK5
C       DTST                  CANNED COPY OF PARTICLES ALOFT INPUT TAPE LNK5
C                             IDENTIFICATION LITERAL (IPARIN)           LNK5
C       DUMPP                 SUBROUTINE     SELECTS AND DUMPS ONE OR MORE  LNK5
C                             SETS OF PARTICLE DESCRIPTIONS ONTO TEMPORARY,OR LNK5
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C                   INTERMEDIATE OUTPUT TAPES.                          LNK5  61
C     ENDTIM        TIME UP TO WHICH THE CURRENT WIND FIELD DESCRIPTLNK5  62
C                   ION IS ASSUMED TO BE VALID.                         LNK5  63
C     EPSIL         A SMALL NUMBER                                      LNK5  64
C     ERROR         SUBROUTINE    ERROR COMMENT AND/OR STOP             LNK5  65
C     FALRAT        SUBROUTINE   PARTICLE SETTLING RATE COMPUTATION LNK5  66
C     FMAS(J)       MASS PER UNIT AREA (MKS) ASSOCIATED WITH THE        LNK5  67
C                   J-TH CLOUD SUBDIVISION (PARTICLE) AT THE TIME OFLNK5  68
C                   ITS DEFINITION                                      LNK5  69
C     FROG          A PRECOMPUTED CONSTANT INPUT FOR SUBROUTINE         LNK5  70
C                   FALRAT                                              LNK5  71
C     FV            OUTPUT ARGUMENT OF FALRAT (MKS)  A POSITIVE         LNK5  72
C                   QUANTITY                                            LNK5  73
C     FW            FISSION YIELD                                       LNK5  74
C     GETWND        SUBROUTINE   GETS MACRO WIND VECTORS AT PARTICLELNK5  75
C                   POSITION                                            LNK5  76
C     H             OUTPUT ARGUMENT OF SUBROUTINE HEIGHT                LNK5  77
C     HEIGHT        SUBROUTINE   RETRIEVES TOPO HEIGHT AT X,Y           LNK5  78
C     HOB           HEIGHT OF BURST RELATIVE TO SURFACE HEIGHT          LNK5  79
C     HS            TEMPORARY STORAGE FOR STANDARD ATMOSPHERIC          LNK5  80
C                   STRATUM BOTTOM HEIGHT                               LNK5  81
C     HTOPO         HEIGHEST TOPO HEIGHT ANYWHERE ON THE TOPO TAPE      LNK5  82
C     HTST          CANNED COPY OF TOPOGRAPHY TAPE IDENTIFICATION       LNK5  83
C                   LITERAL (IHTOPO)                                    LNK5  84
C     IBADD(K)      BASE ADDRESS OF KTH WIND DATA BLOCK IN ARRAYS       LNK5  85
C                VX, VY, AND VZ                                         LNK5  86
C     IBYPAS        INITIALIZE BYPASS FLAG                              LNK5  87
C                                                                       LNK5  88
C     IC(J)         CONTROL VARIABLES   INTERPRETATIONS AS FOLLOWS      LNK5  89
C        1          SUPRESS TOPO TAPE USEAGE IF= 1                      LNK5  90
C        2          SUPRESS OFF TOPO TAPE USEAGE IF = 1                 LNK5  91
C        3          SUPRESS OUT OF WIND FIELD TAPE USEAGE IF = 1        LNK5  92
C        4          SUPRESS PARTICLES ALOFT SECONDARY MEMORY IF = 1 LNK5  93
C        5          SUPRESS ALL TAPE SECONDARY MEMORY                   LNK5  94
C        6          TRANSPORT TRACE CONTROL.  0 = NO TRACES,            LNK5  95
C                   1 = A PARTIAL TRACE,  2 =  A MORE COMPLETE TRACELNK5  96
C        7          PRINT WIND FIELD IF  = 1                            LNK5  97
C        8          SUPRESS PRINT AND WRITE OF LOST PARTICLES IF = 1LNK5  98
C                                                                       LNK5  99
C                                                                       LNK5 100
C     IEXEC         EXECUTIVE CONTROL WORD TO CONTROL BRANCHING         LNK5 101
C                   BETWEEN CHAIN LINK SUBROUTINES                      LNK5 102
C     IF            INDEX OF THE LAST LINE IN THE PARTICLE ARRAYS       LNK5 103
C     II            ITOPLM(1,J) FOR THE TOPO DATA BLOCK CURRENTLY INLNK5 104
C                   CORE                                                LNK5 105
C     IL(K)         LIMITS ON INDICES OF WIND BLOCK DATA SET K          LNK5 106
C     ILIM                                                              LNK5 107
C     IPAS          ASSIGNED GO TO VARIABLE FOR USE IN DEALING WITH LNK5 108
C                   EXCESSIVELY SMALL PARTICLE MOVEMENTS ARISING        LNK5 109
C                   DURING TRANSPORT                                    LNK5 110
C     IR            INDICATOR OF TYPE OF BOUNDING PLANE ENCOUNTERED LNK5 111
C                   DURING TRANSPORT.  1=X-BOUNDARY, 2=Y-BOUNDARY,      LNK5 112
C                   3=Z-BOUNDARY, 4= TIME BOUNDARY, 5= LOCAL CIRC-      LNK5 113
C                   ULATION CELL BOUNDARY.                              LNK5 114
C     IRROR         NUMBER OF THE SOURCE STATEMENT NEAREST TO WHERE LNK5 115
C                   AN ERROR CONDITION WAS SENSED.                      LNK5 116
C                   THAT IS TO BE PROCESSED BY THE TRANSPORT LOOP       LNK5 117
C     IT            ASSIGNED GO TO VARIABLE FOR USE IN CODE SELECT-     LNK5 118
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C                       ION REGARDING USE OF PLANAR OR PIECEWISE PLANAR LNK5 119
C                       TOPOGRAPHIC DESCRIPTION.                        LNK5 120
C     ITOPLM(1,J)       NUMBER OF CELLS IN THE X DIRECTION OF THE       LNK5 121
C                       REGULAR GRID SECTION OF THE J-TH TOPO DATA BLOCKLNK5 122
C     ITOPLM(2,J)       SEE ITOPLM(1,J)  BUT FOR Y-DIRECTION            LNK5 123
C     ITOPLM(3,J)       NUMBER OF ENTRIES IN THE ONE-DIMENSIONAL SUB-   LNK5 124
C                       SIDIARY TOPOGRAPHIC DATA ARRAY FOR THE J-TH     LNK5 125
C                       DATA BLOCK                                      LNK5 126
C     ITT               SEE IT.                                         LNK5 127
C     JDONE             IF 1, INDICATES THAT THE ONLY PARTICLES THAT RE-LNK5 128
C                       MAIN TO HAVE THEIR TRANSPORT COMPLETED ARE      LNK5 129
C                       CURRENTLY IN CORE MEMORY.  NONE ARE ON THE TIME LNK5 130
C                       BOUNDARY TAPE.                                  LNK5 131
C     JFTOPO            INDICATOR OF TOPO TAPE FILE POSITION            LNK5 132
C                       THIS WORD RECORDS THE NUMBER OF THE FILE        LNK5 133
C                       WHICH A READ COMMAND WOULD BRING IN NEXT.       LNK5 134
C     JJ                ITOPLM(2,J) FOR THE TOPO DATA BLOCK CURRENTLY INLNK5 135
C                       CORE                                            LNK5 136
C     JL(K)                                                             LNK5 137
C     JLIM                                                              LNK5 138
C     JTEST             TEMPORARY STORAGE                               LNK5 139
C     JTEST1                                                            LNK5 140
C           +1          THE TIME BOUNDARY TAPE IS IN USE                LNK5 141
C            0          NO TIME BOUNDARY PARTICLES ARE ON TAPE          LNK5 142
C           -1          USED ONLY TO CAUSE AN ENTRANCE TO MAIN TRANSPORTLNK5 143
C                       LOOP WITHOUT FIRST  READING MORE PARTICLES FROM LNK5 144
C                       TAPE.  THUS  ALL TRANS PORTABLE PARTICLES       LNK5 145
C                       REMAINING IN CORE ARE TRANSPORTED JUST AFTER A  LNK5 146
C                       NEW WIND FIELD HAS BEEN COMPUTED.               LNK5 147
C     JTEST2            TEMPORARY STORAGE                               LNK5 148
C     JTIME1            INDICATES THE PRESENCE OF PARTICLES ON THE TIME LNK5 149
C                       BOUNDARY TAPE                                   LNK5 150
C                       +1 INDICATES THAT THE TIME BOUNDARY TAPE IS IN  LNK5 151
C                       USE.   0 INDICATES THAT IT IS NOT IN USE.       LNK5 152
C                       -1 INDICATES THAT THERE ARE TIME BOUNDARY       LNK5 153
C                       PARTICLES IN CORE.  -1 IS USED TO CAUSE AN      LNK5 154
C                       ENTRANCE TO THE MAIN LOOP WITHOUT FIRST         LNK5 155
C                       READING MORE PARTICLES IN SO AS TO TRANSPORT    LNK5 156
C                       ALL TRANSPORTABLE PARTICLES THAT REMAIN IN      LNK5 157
C                       MEMORY JUST AFTER A NEW WIND FIELD IS COMPUTED. LNK5 158
C     JTOPJ             INDEX OF HIGHEST WIND LAYER.  SET BY MKWIND OR  LNK5 159
C                       LINK 6                                          LNK5 160
C     JTOP1             FLAG FOR PARTICLES OFF THE IN CORE TOPO GRID    LNK5 161
C     JW                USED BY LINK7 AND SUBROUTINES AS AN INDEX OF THELNK5 162
C                       WIND STRATUM CONTAINING A PARTICLE              LNK5 163
C     JWAD              INDEX OF MACRO WIND CELL CONTAINING PARTICLE    LNK5 164
C     JWAD1             TEMPORARY STORAGE FOR PRECEEDING VALUE OF JWAD  LNK5 165
C     JWIND1            FLAG FOR PARTICLES OUT OF IN CORE WIND SPEC     LNK5 166
C     KLIM              LIMITS ON INDICES OF TOPO ARRAYS                LNK5 167
C     KK                ITOPLM(3,J) FOR THE TOPO DATA BLOCK CURRENTLY INLNK5 168
C                       CORE                                            LNK5 169
C     LOTRAN            SUBROUTINE    LOCAL SYSTEM PARTICLE TRANSPORT   LNK5 170
C                       CODE                                            LNK5 171
C     MXTOPO            MAX. NO. TOPO BLOCK CAPABILITY OF PROGRAM       LNK5 172
C     MPNT              USED TO CONTROL THE AMOUNT OF TRANSPORT TRACE   LNK5 173
C                       PRINTING IN LINK 7.  1=NO PRINTING, 2=PRINT ALL LNK5 174
C                       TRACES.                                         LNK5 175
C     MTWND1            SUBROUTINE    MOUNTAIN WIND CIRCULATION MODEL   LNK5 176
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C       N              NUMBER OF PARTICLE DESCRIPTIONS ABOUT TO BE READLNK5 177
C                      FROM THE CURRENT BLOCK OF THE PARTICLES INPUT   LNK5 178
C                      TAPE                                            LNK5 179
C       NA             NUMBER OF ATMOSPHERIC LEVELS DESCRIBED IN THE   LNK5 180
C                      TABLES OF STANDARD ATMOSPHERIC DENSITY AND      LNK5 181
C                      VISCOSITY                                       LNK5 182
C       NALOFT         SIZE OF ARRAY FOR PARTICLES ALOFT               LNK5 183
C       NBLCK          NUMBER OF BLOCKS OF TOPO DATA ON TOPO TAPE      LNK5 184
C       NBMAX          SIZE LIMIT ON DUMP BLOCK                        LNK5 185
C       NCIR           TEMPORARY STORAGE FOR NCRTYP(J)                 LNK5 186
C       NCL            SPARE                                           LNK5 187
C       NCRTYP(J)      LOCAL CIRCULATION TYPE IDENTIFIER OF THE J-TH   LNK5 188
C                      LOCAL SYSTEM.  1 IS MTWND1, 2 IS RGWND1, 3 IS   LNK5 189
C                      CBREZ1, OTHERS ARE UNASSIGNED.                  LNK5 190
C       NFREE          NUMBER OF EMPTY LINES IN PARTICLES ALOFT LIST   LNK5 191
C       NG             NUMBER OF PARTICLES GROUNDED          (IN CORE) LNK5 192
C       NINTAR(J)      NUMBER OF PARTICLES OVER TOPO AREA J AND IN     LNK5 193
C                      THE OUT-OF-TOPO BUFFER                          LNK5 194
C       NLOCIR         THE NUMBER OF LOCAL CIRCULATION SYSTEMS IN USE  LNK5 195
C       NLOST          NUMBER OF PARTICLES THAT DRIFTED BEYOND LIMITS  LNK5 196
C       NPS            NUMBER OF PARTICLE SIZE RANGES DESCRIBED IN THE LNK5 197
C                      PARTICLE SIZE DISTRIBUTION ARRAYS               LNK5 198
C       NSP            SPARE                                           LNK5 199
C       NSTRAT         MAXIMUM NUMBER OF ATMOSPHERIC STRATUM DESCRIPT- LNK5 200
C                      IONS THAT THE PROGRAM CAN ACCOMODATE            LNK5 201
C       NTI            NUMBER OF PARTICLES AT TIME BARRIER. (IN CORE)  LNK5 202
C       NTO            NUMBER OF PARTICLES AT TOPO BARRIER  (IN CORE)  LNK5 203
C       NUL            INTEGER ZERO                                    LNK5 204
C       NW             NUMBER OF PARTICLES AT WIND BARRIER  (IN CORE)  LNK5 205
C       N1,N2          ASSIGNED GO TO VARIABLES FOR USE IN SPEEDING UP LNK5 206
C                      THE COMPUTATION OF TIME OF FLIGHT TO LOCAL CIRC-LNK5 207
C                      ULATION SYSTEM CELL BOUNDARIES.                 LNK5 208
C       POUT           CANNED COPY OF GROUNDED PARTICLES TAPE IDENT-   LNK5 209
C                      IFIER LITERAL (IPOUT )                          LNK5 210
C       PROGRM         CONTAINS PROGRAM NAME IN BCD                    LNK5 211
C       PS(J)          MID-RANGE PARTICLE SIZE (MICRONS) OF THE J-TH   LNK5 212
C                      PARTICLE SIZE RANGE DESCRIBED IN THE PARTICLE   LNK5 213
C                      SIZE DISTRIBUTION ARRAYS                        LNK5 214
C       PSEID          PARTICLE SET EXPANSION  PROGRAM OF INTERFACE    LNK5 215
C                      PROGRAM RUN IDENTIFICATION                      LNK5 216
C       PSIZE          TEMPORARY STORAGE FOR PARTICLE SIZE OF CURRENT  LNK5 217
C                      PARTICLE                                        LNK5 218
C       RADMAX         MAXIMUM CLOUD RADIUS DURING CLOUD RISE          LNK5 219
C       RDTOPO         SUBROUTINE  READS IN A TOPO DATA BLOCK          LNK5 220
C       RGWND1         SUBROUTINE    RIDGE WIND CIRCULATION MODEL      LNK5 221
C       RHO(J)         ATMOSPHERIC DENSITY IN THE J-TH TABULATED       LNK5 222
C                      STRATUM                                         LNK5 223
C       ROPART         FALLOUT PARTICLE DENSITY (MKS)                  LNK5 224
C       RTST           TEMPORARY STORAGE                               LNK5 225
C       SIGMA          STANDARD DEVIATION OF PARTICLE SIZE DISTRIBUTIONLNK5 226
C       SLDTMP         PARTICLE SOLIDIFACATION TEMPERATURE (K)         LNK5 227
C                                                                      LNK5 228
C       SSAM           MASS OF CONDENSED PHASE MATERIAL AT SPECIFICAT- LNK5 229
C                      ION TIME                                        LNK5 230
C       TC             TEMPORARY STORAGE                               LNK5 231
C       TGZ            TIME OF DETONATION                              LNK5 232
C       TID( )         TRANSPORT IDENTIFICATION                        LNK5 233
C       TIX,TIY,TIZ    TIMES OF FLIGHT TO THE FIRST X,Y,AND Z MACRO    LNK5 234
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C                       CELL BOUNDING PLANES                            LNK5 235
C     TLIMIT            TIME SPECIFIED FOR THE TERMINATION OF TRANSPORT LNK5 236
C     TMAXX,TMAXY       TEMPORARY STORAGE FOR LARGEST OF (TX1,TX2) AND  LNK5 237
C                       (TY1,TY2)                                       LNK5 238
C     TMINX,TMINY       TEMPORARY STORAGE FOR SMALLEST OF (TX1,TX2) AND LNK5 239
C                       (TY1,TY2) RESPECTIVELY                          LNK5 240
C     TMSD              TIME OF SOLIDIFICATION                          LNK5 241
C     TOPID(J)          TOPOGRAPHY IDENTIFIER                           LNK5 242
C     TOPOLM            FLOATING POINT TOPOGRAPHIC DATA ARRAY           LNK5 243
C     TOPOLM(1,J)       MIN. X-COORDINATE FOR J-TH TOPO DATA BLOCK      LNK5 244
C     TOPOLM(2,J)       MIN. Y-COORDINATE FOR J-TH TOPO DATA BLOCK      LNK5 245
C     TOPOLM(3,J)       INITIAL (REGULAR) GRID INTERVAL FOR J-TH TOPO   LNK5 246
C                       DATA BLOCK                                      LNK5 247
C     TOPOLM(4,J)       HEIGHEST TOPO HEIGHT IN THE J-TH TOPO DATA BLOCKLNK5 248
C     TP                PARTICLE TIME STATUS                            LNK5 249
C     TS                TIME OF FLIGHT TO POINT OF ENTRANCE TO CURRENT  LNK5 250
C                       LOCAL WIND CELL                                 LNK5 251
C     TTOPO             HEIGHEST TOPO ELEVATION IN THE IN CORE DATA     LNK5 252
C     TW                TOTAL YIELD                                     LNK5 253
C     TWND              TIME OF FLIGHT TO TIME BOUNDARY                 LNK5 254
C     TXLL,TXLU,TYLL,   LOWER AND UPPER X AND Y COORDINATE LIMITS FOR   LNK5 255
C     TX1,TX2           TIMES OF FLIGHT TO THE TWO X-PLANES BOUNDING THELNK5 256
C                       CURRENT LOCAL CIRCULATION CELL.                 LNK5 257
C     TYLU              THE AREA ACCOUNTED FOR ON THE TOPOGRAPHY TAPE   LNK5 258
C     TY1,TY2           SEE TX1 BUT FOR Y-PLANES                        LNK5 259
C     VPX,VPY           TEMPORARY STORAGE FOR X AND Y PARTICLE VELOCITY LNK5 260
C     VPZ               NET VERTICAL VELOCITY OF PARTICLE               LNK5 261
C     VPZT              TEMPORARY STORAGE FOR PRECEEDING VALUE OF VPZ   LNK5 262
C     VX, VY, VZ        WIND VELOCITY COMPONENTS                        LNK5 263
C     WGRINT(K)         GRID INTERVAL OF KTH WIND DATA BLOCK            LNK5 264
C     WID(J)            WIND FIELD DESCRIPTION IDENTIFICATION           LNK5 265
C     WLLX(K)           HORIZONTAL LIMITS OF KTH WIND DATA BLOCK        LNK5 266
C     WURY(K)           HORIZONTAL LIMITS OF KTH WIND DATA BLOCK        LNK5 267
C     X,Y               TEMPORARY STORAGE FOR PARTICLE COORDINATES      LNK5 268
C     XBL,XBU           LOWER AND UPPER X COORDINATES OF MACRO CELL CON-LNK5 269
C                       TAINING PARTICLE                                LNK5 270
C     XGZ,YGZ           COORDINATES OF GROUND ZERO                      LNK5 271
C     XIN,YIN,ZIN       X,Y,AND Z INCREMENTAL DISTANCES FOR USE IN      LNK5 272
C                       CONSTANT TIME INTERVAL STEPPING BELOW MAXIMUM   LNK5 273
C                       TOPO HEIGHT.                                    LNK5 274
C     XP, YP, ZP        PARTICLE POSITION COORDINATES                   LNK5 275
C     XX,YY,ZZ          TEMPORARY STORAGE FOR X,Y,AND Z PARTICLE COORDINLNK5 276
C                       ATES                                            LNK5 277
C     YBL,YBU           SEE XBL.   FOR Y COORDINATE                     LNK5 278
C                                                                       LNK5 279
C **********************************************************************LNK5 280
      COMMON /SET1/                                                     LNK5 281
     1        DIAM   ,DETID(12),IRISE  , IEXEC  , ISIN   , ISOUT     ,  LNK5 282
     2        SD     , SPAR    , SSAM  , TME    , TMP1   , TMP2      ,  LNK5 283
     3        TZM    , U       , VPR   , W      , X      , Z         ,  LNK5 284
     4        WHY(40), RMIN    , IDISTR, SPAR1  , SPAR2  , JDONE     ,  LNK5 285
     5        SPAR4  , SPAR5   , SPAR6 , SPAR7  , SPAR8  , SPAR9        LNK5 286
C                                                                       LNK5 287
C **********************************************************************LNK5 288
C                                                                       LNK5 289
      COMMON /SET2/                                                     LNK5 290
     1        S      , SUBSID  , GRINT , BXLL   , BXLU   , BYLL         LNK5 291
     2,       BYLU   , TXLL    , TXLU  , TYLL   , TYLU   , XGZ          LNK5 292
     3,          YGZ     , NBLCK   , HTOPO   , TTOPO   , ILIM    , JLIM           LNK5 293
     4,          KLIM    , II      , JJ      , KK      , XP      , YP             LNK5 294
     5,          ZP      , FMAS    , TP      , PS      , VX      , VY             LNK5 295
     6,          VZ      , IL      , JL      , IBADD   , WGRINT  , NSTRAT         LNK5 296
     7,          WLLX    , WLLY    , WURX    , WURY    , BOTHIT  , IPARIN         LNK5 297
     8,          IOTOPO  , IOWIND  , IHTOPO  , IPOUT   , IPAROT  , JTOP1 !        LNK5 298
     9,          JWIND1  , IRROR   , TLIMIT  , ENDTIM  , IC      , IBYPAS         LNK5 299
     1,          JTOPJ   , NLOST   , NG      , NTO     , NTI     , NW             LNK5 300
     2,          NALOFT  , JTIME1  , NBMAX · , NFREE   , N       , NCL            LNK5 301
     3,          CRMAXY  , CROHT   , NCRTYP  , BZ      , CRMINX  , CRMINY         LNK5 302
     4,          UU      , SN      , CS      , NLOCIR  , DTLOC   , ATEMP          LNK5 303
     5,          RHO     , MA      , TGZ     , DTMAC   , FROG    , CRMAXX         LNK5 304
     6,          ROPART                                                         LNK5 305
      DIMENSION TOPOLM(4,4)   ,NINTAR(4)      ,ITOPLM(3,4)                      LNK5 306
      DIMENSION S(10,10)      ,SUBSID(400)    ,IC(18)                           LNK5 307
      DIMENSION XP(200)       ,YP(200)        ,ZP(200)        ,FMAS(200)        LNK5 308
      DIMENSION TP(200)       ,PS(200)        ,ATEMP(260)     ,RHO(260)         LNK5 309
      DIMENSION VX(1500)      ,VY(1500)       ,VZ(1500)       ,IL(70)           LNK5 310
      DIMENSION JL(70)        ,IBADD(70)      ,WURX(70)                         LNK5 311
      DIMENSION WGRINT(70)                    ,WLLX(70)       ,WLLY(70)         LNK5 312
      DIMENSION WURY(70)      ,BOTHIT(70)     ,SN(6)          ,CS(6)            LNK5 313
      DIMENSION CRMINX(6)     ,CRMAXX(6)      ,CRMINY(6)      ,CRMAXY(5)        LNK5 314
      DIMENSION CROHT(6)      ,NCRTYP(6)      ,UU(6)                            LNK5 315
C                                                                               LNK5 316
C *******************************************************************************LNK5 317
C                                                                               LNK5 318
      DIMENSION CRID(12)      ,PSEID(12)      ,TID(12)                          LNK5 319
      DIMENSION WID(12)       ,TOPID(12)                                        LNK5 320
 1    FORMAT(12A6)                                                              LNK5 321
 2    FORMAT(///25X,56H****  INITIAL CONDITIONS (FIREBALL) IDENTIFICATIOLNK5 322
     1N  ****/25X,12A6,//25X,37H****  CLOUD RISE IDENTIFICATION  ****/25LNK5 323
     2X,12A6,//25X,49H****  PARTICLE SET EXPANSION IDENTIFICATION  **** LNK5 324
     3     /25X,12A6//25X,83H****  THIS RUN OF THE TRANSPORT MODULE WAS LNK5 325
     4GIVEN THE FOLLOWING IDENTIFICATION  ****/25X,12A6///25X,28H****  OLNK5 326
     5THER INPUT DATA  ****)                                            LNK5 327
 3    FORMAT(18X,12A6)                                                  LNK5 328
 4    FORMAT(I5)                                                        LNK5 329
 5    FORMAT(2E12.5)                                                    LNK5 330
 6    FORMAT(1H1,24X,48HATMOSPHERIC PROPERTIES FOR FALL RATE CALCULATIONLNK5 331
     1//25X16HHEIGHT OF BOTTOM4X,9HVISCOSITY12X,7HDENSITY/26X10HOF STRATLNK5 332
     2UM/25X16HMETERS ABOVE MSL6X5H(MKS)15X5H(MKS)//)                   LNK5 333
 7    FORMAT(/15X71HTHE CONTROL VARIABLE ARRAY, IC(J), HAS BEEN GIVEN THLNK5 334
     1E FOLLOWING VALUES.)                                              LNK5 335
 8    FORMAT(15X,18I4)                                                  LNK5 336
 9    FORMAT(/15X28HTHE TRANSPORT TIME LIMIT IS F12.3)                  LNK5 337
 10   FORMAT(18X63H IN THIS RUN WE ASSUME A PLANAR DEPOSITION SURFACE ATLNK5 338
     1 ELEVATIONF10.3)                                                  LNK5 339
 11   FORMAT(42H0PARTICLES REMAINING ON TIME BOUNDARY TAPE)             LNK5 340
 12   FORMAT(6(1X,E13.6))                                               LNK5 341
 13   FORMAT(A6,4F10.3,I3)                                              LNK5 342
 14   FORMAT(29H0 WRONG TAPE REEL ON DRIVE   I2)                        LNK5 343
 15   FORMAT(42H0PLEASE MOUNT CORRECT TAPE AND PRESS START)             LNK5 344
 16   FORMAT(/18X,35HIDENTIFICATION FROM TOPOGRAPHY TAPE18X12A6)        LNK5 345
 17   FORMAT(25X,E13.5,5X,E13.5,6X,E13.5)                               LNK5 346
 18   FORMAT(58H0TRANSPORT IS COMPLETED. INTERMEDIATE RESULTS ARE ON TAPLNK5 347
     1E I2)                                                             LNK5 348
 19   FORMAT(44H0PLEASE FILE PROTECT THE REEL ON TAPE DRIVE I2,25H  AT TLNK5 349
     1HE END OF THIS RUN.)                                              LNK5 350
 20   FØRMAT(6F10.5)
 21   FØRMAT(18I4)
 22   FØRMAT(A6,I3,4E12.5,I5)
 23   FØRMAT(1H1///51X19H* * * * * * * * * *//12X101HT H E   D E P A R T
     1 M E N T   Ø F   D E F E N S E   F A L L Ø U T   P R E D I C T I Ø
     2 N   S Y S T E M,//51X,19H* * * * * * * * * *////52X,16HTRANSPØRT
     3MØDULE///55X,11HPREPARED BY/43X,34HTECHNICAL ØPERATIØNS RESEARCH,I
     4NC./52X,17HBURLINGTØN, MASS.////29X,63H****  SUMMARY ØF INPUT IDEN
     5TIFIERS AND INITIAL CØNDITIØNS  ****)

 24   FØRMAT(//15X16HTØPØGRAPHIC DATA)
 27   FØRMAT(//15X13HPARTICLE DATA/18X28HDENSITY ØF FALLØUT PARTICLESF20
     1.3,2X,7HKG/M**3)
 28   FØRMAT(//15X9HWIND DATA/)
 29   FØRMAT(18X,A6,1X,I6,4(1X,E13.5),1X,I10)
 30   FØRMAT(18X,A6,4(1X,F13.5),I6)
 31   FØRMAT(6F12.3)
C
C **********************************************************************
C
      DATA HTST,DTST,BLANK,PØUT,ENDWFD/6HIHTØPØ,6HIPARIN,6H      ,6HIPØU
     1T ,6HEND ØF/
C
C **********************************************************************
C **********************************************************************
C
C     THIS BYPASSES INITIALIZATIØN CØDING AFTER THE FIRST PASS
      NUL=0
      IF (IBYPAS-918273)201,200,201
 201  IBYPAS=918273
C     INITIALIZE
      JDØNE=0
      IPARIN=11
      IØTØPØ=4
      IØWIND=3
      IHTØPØ=10
      IPØUT= 9
      IPARØT=1
      JTØP1=0
      JWIND1=0
      JTIME1=0
      ENDTIM=0.0
      JFTØPØ=1
      MXTØPØ=4
      DTMAC=10.
      DTLØC=10.
      NALØFT=200
      NBMAX=150
      NFREE=NALØFT
      NLØST=0
      NSTRAT =70
      NW=0
      NTØ=0
      NG=0
C
C     ILIM,JLIM,KLIM,ARE LIMITS ØN TØPØ ARRAYS. SEE DIMENSIØN.
      ILIM=10
      JLIM=10
      KLIM=400
      DO 2011 J=1,NALOFT
 2011 FMAS(J)=0.0
C
C     READ IDENTIFICATION FOR TRANSPORT
      READ (ISIN,1)(TID(J),J=1,12)
C
C     READ CONTROL DATA FOR TRANSPORT
C     THESE CONTROL PARAMETERS ARE FOR USE AS SIMPLIFYING SWITCHES
      READ (ISIN,21)(IC(J),J=1,18)
      READ (ISIN,31)TLIMIT
C
C     REWIND ALL TAPES INVOLVED IN TRANSPORT
      IF(IC(1)-1)150,151,151
  150 REWIND IHTOPO
  151 IF(IC(2)-1)152,153,153
  152 REWIND IOTOPO
  153 IF(IC(3)-1)154,155,155
  154 REWIND IOWIND
  155 IF(IC(4)-1)156,157,157
  156 REWIND IPAROT
  157 CONTINUE
      REWIND IPARIN
      REWIND IPOUT
C
C     CHECK IDENTIFICATIONS ON TOPO AND PARTICLE INPUT TAPES
  206 IF(IC(1)-1)158,203,203
  158 READ (IHTOPO)DENTI
      RTST=AND(DENTI,COMPL(HTST))
      IF(RTST)202,2031,202
C
C 202  WRONG TAPE AS IHTOPO
  202 PRINT 14,IHTOPO
      WRITE (ISOUT,14)IHTOPO
      PRINT 15
      REWIND IHTOPO
      PAUSE
      REWIND IHTOPO
      GO TO 206
C
C 204  WRONG TAPE AS IPARIN
  204 PRINT 14,IPARIN
      WRITE (ISOUT,14)IPARIN
      PRINT 15
      REWIND IPARIN
      PAUSE
      REWIND IPARIN
      GO TO 207
 2031 READ(IHTOPO)TXLL,TXLU,TYLL,TYLU,NBLCK
C
  203 CONTINUE
  207 READ (IPARIN)DENTT
      RTST=AND(DENTT,COMPL(DTST))
      IF(RTST)204,208,204
C
C 208 READ ARBITRARY 72 CHARACTER FIREBALL,CLOUD-RISE,AND PARTICLE
C     ACTIVITY IDENTIFICATIONS FROM IPARIN
  208 READ (IPARIN) FW,SSAM,SLDTMP,TMSD,SIGMA,TW,HOB,NSP,XGZ,YGZ,TGZ,BZ,
     1 NCL,RADMAX
```

```
      READ (IPARIN)(PSEID(J),J=1,12)
      READ (IPARIN)(CRID(J),J=1,12)
      READ (IPARIN)(DETID(J),J=1,12)
C
C     READ DENSITY OF FALLOUT PARTICLES
C     ROPART IS PARTICLE DENSITY IN KILOGRAMS PER CUBIC METER
      READ (IPARIN)ROPART
C
C     READ PARTICLE SIZE MASS AND ACTIVITY DISTRIBUTIONS
      READ (IPARIN)NPS
C
C     VX(  ) IS USED TO TEMPORARILY STORE THE SURFACE TO VOLUME RATIO
C     ARRAY SV
C     VY(  ) IS USED TO TEMPORARILY STORE THE A ARRAY FROM PSE (LINK4)
C     VZ(  ) IS USED TO TEMPORARILY STORE THE PACT ARRAY FROM PSE(LINK4)
      READ (IPARIN)(PS(I),VY(I),VZ(I),VX(I),I=1,NPS)
C
C     READ ATMOSPHERIC DENSITY AND VISCOSITY
C     A TABLE OF ATMOSPHERIC VISCOSITY (ATEMP(J)) AND DENSITY (RHO(J))
C     STATED IN THE MKS SYSTEM FOR 200 METER STRATA STARTING FROM 1100
C     METERS BELOW MSL
      READ (IPARIN)NA
      READ (IPARIN)(ATEMP(J),RHO(J),J=1,NA)
C
C     COMPUTE CONSTANT FOR FALL RATE CALCULATIONS
      FROG=1.3066667E-17*ROPART
C
C     READ ARBITRARY TOPO IDENTIFICATION
      IF(IC(1)-1)159,160,160
 160  READ (ISIN,20)TTOPO
      GO TO 205
 159  READ (IHTOPO)(TOPID(J),J=1,12)
C
C     READ TOPO TABLE OF CONTENTS
      READ (IHTOPO)TOPOLM
      READ (IHTOPO)ITOPLM
C
C     FIND HIGHEST TOPO HEIGHT
      HTOPO=0.0
      DO 170 J=1,NBLCK
      IF(HTOPO-TOPOLM(4,J))171,170,170
 171  HTOPO=TOPOLM(4,J)
 170  CONTINUE
C
C     READ FIRST TOPO DATA BLOCK
      CALL RDTOPO (1)
C
C 205  PUT AN IDENTIFICATION ON THE TRANSPORT INTERMEDIATE OUTPUT TAPE
 205  READ (ISIN,1)(WID(J),J=1,12)
      WRITE (IPOUT)POUT
      WRITE(IPOUT ) FW,SSAM,SLDIMP,IMOD,SIGMA,TW,HOB,NCL,TLIMIT,BZ,
     1 ROPART,XGZ,YGZ,ICZ,RADMAX
      WRITE (IPOUT) (DETID(J),J=1,12),(CRID(J),J=1,12),(PSEID(J),J=1,12)
     1,(TID(J),J=1,12),(WID(J),J=1,12)
      WRITE (IPOUT)NPS
      WRITE (IPOUT)(PS(J),VY(J),VZ(J),VX(J),J=1,NPS)
      IF(IC(1)-1)2054,2055,2054
 2055 CONTINUE
```

```
      WRITE (IPOUT) (BLANK,J=1,12)
      GO TO 2056
 2054 WRITE (IPOUT)(TOPID(J),J=1,12)
C
C     PRINT TRANSPORT OUTPUT HEADING
 2056 WRITE (ISOUT,23)
      WRITE (ISOUT,2) (DETID(J),J=1,12),(CRID(J),J=1,12),(PSLID(J),J=1,1
     112),(TID(J),J=1,12)
      WRITE (ISOUT,7)
      WRITE (ISOUT,8)(IC(J),J=1,18)
      WRITE (ISOUT,9)TLIMIT
      WRITE (ISOUT,27)ROPART
      WRITE (ISOUT,29)DENTI,NSP,XGZ,YGZ,TGZ,BZ,NCL
      WRITE (ISOUT,24)
      IF(IC(1)-1)2051,2052,2051
 2052 WRITE (ISOUT,10)TTOPO
      GO TO 2053
 2051 WRITE (ISOUT,16)(TOPID(J),J=1,12)
      WRITE (ISOUT,30)DENTI,TXLL,TXLU,TYLL,TYLU,NBLCK
 2053 WRITE (ISOUT,28)
      WRITE (ISOUT,3)(WID(J),J=1,12)
      WRITE(ISOUT,6)
      HS=-1100.0
      DO 2057 J=1,NA
      WRITE(ISOUT,17)HS,ATEMP(J),RHO(J)
 2057 HS=HS+200.0
C
C ***********************************************************************
C
C 200 ANY MORE TIME INTERVALS TO BE DEALT WITH.     NO TO 500
  200 IF(TLIMIT-ENDTIM)500,500,400
C
C 500 MAKE FINAL TRANSPORT PROGRAM OUTPUT AND COMMENTS
C     SET N=NALOFT TO CAUSE  DUMPP  TO CLEAR OUT THE ENTIRE PARTICLE ARR
C
 500  N=NALOFT
      CALL DUMPP
C
C     ARE ANY PARTICLES ON THE TIME BOUNDARY TAPE.   YES TO 700
C********************      TEMP      ***********************************
      JTIME1=0
      IF(JTIME1)501,501,700
C
C 700  PRINT ANY PARTICLE DESCRIPTIONS THAT REMAIN ON THE TIME BOUNDARY
C     OVERFLOW TAPE, IPAROT
 700  WRITE(IPAROT)NUL
      REWIND IPAROT
      WRITE (ISOUT,11)
 702  READ (IPAROT)N
      IF(N)501,501,701
 701  READ (IPAROT)(XP(J),YP(J),ZP(J),TP(J),PS(J),FMAS(J),J=1,N)
      WRITE (ISOUT,12)(XP(J),YP(J),ZP(J),TP(J),PS(J),FMAS(J),J=1,N)
      GO TO 702
C
C 501  WRITE A FINAL ZERO BLOCK COUNT AND EOF ON IPOUT
 501  WRITE (IPOUT)NUL
      END FILE IPOUT
      REWIND IPOUT
      WRITE (ISOUT,18)IPOUT                                             LNK5 583
      PRINT 18,IPOUT                                                    LNK5 584
      PRINT 19,IPOUT                                                    LNK5 585
C                                                                       LNK5 586
C 5010  SKIP OVER ANY UNUSED WIND DATA                                  LNK5 587
C     A CARD CONTAINING 'END OF WIND FIELD DATA' MUST MARK THE END OF   LNK5 588
C     THE WIND FIELD DATA DECK                                          LNK5 589
 5010 READ(ISIN,1)RTST                                                  LNK5 590
      RTST=AND(ENDWFD,COMPL(RTST))                                      LNK5 591
      IF(RTST)5010,800,5010                                             LNK5 592
C                                                                       LNK5 593
C 800 PREPARE TO CALL OUTPUT PROCESSOR PROGRAM                          LNK5 594
 800  IEXEC=2                                                           LNK5 595
      RETURN                                                            LNK5 596
C                                                                       LNK5 597
C 400 GET OR OTHERWISE PRODUCE THE NEXT TIME INTERVAL'S WIND FIELD.     LNK5 598
 400  NTI=0                                                             LNK5 599
      IEXEC = 1                                                         LNK5 600
      RETURN                                                            LNK5 601
      END                                                               LNK5 602
                                                                            603*

                                                                            603 *
```

```
$IBFTC LNK6     LIST,DECK,M94/2                                                              LNK6
      SUBROUTINE LINK6                                                                       LNK6    1
      CALL MKWIND                                                                            LNK6    2
      RETURN                                                                                 LNK6    3
      END                                                                                    LNK6    4
                                                                                                          5*

                                                                                                          5  *
```

```
$IBFTC RDCIR    LIST,DECK,M94/2                                         RDCI
      SUBROUTINE RDCIRS                                                 RDCI
C     12 OCT 66                                                         RDCI
C     T.W.SCHWENKE       TECHNICAL OPERATIONS RESEARCH, INC.            RDCI
C                                                                       RDCI
C ********************************************************************RDCI
C                                                                       RDCI
C     THIS PROGRAM READS LOCAL CIRCULATION SYSTEM INPUTS.  IT READS    RDCI
C     SYSTEM COORDINATE LIMITS, CIRMINX( ),CRMAXX( ),CRMINY( ),CRMAX(Y( RDCI
C     THE INDEX OF THE APPLICABLE COMPUTATION CODE FOR EACH LOCAL       RDCI
C     SYSTEM IS STORED IN NCRTYP( )                                     RDCI
C     A COUNT OF THE NUMBER OF LOCAL SYSTEMS IS RECORDED IN NLOCIR      RDCI
C                                                                       RDCI
C ********************************************************************RDCI
C                                                                       RDCI
      COMMON /SET1/                                                     RDCI
     1          DIAM    , DETID  , IRISE  , IEXEC  , ISIN   , ISOUT   , RDCI
     2          SD      , SPAR   , SSAM   , TME    , TMP1   , TMP2    , RDCI
     3          T2M     , U      , VPR    , W      , X      , Z       , RDCI
     4          WHY     , RMIN   , IDISTR , SPAR1  , SPAR2  , SPAR3   , RDCI
     5          SPAR4   , SPAR5  , SPAR6  , SPAR7  , SPAR8  , SPAR9     RDCI
      DIMENSION  DETID(12),WHY(40)                                      RDCI
C                                                                       RDCI
C ********************************************************************RDCI
C                                                                       RDCI
      COMMON /SET2/                                                     RDCI
     1          S       , SUBSID , GRINT  , BXLL   , BXLU   , BYLL      RDCI
     2,         BYLU    , TXLL   , TXLU   , TYLL   , TYLU   , XGZ       RDCI
     3,         YGZ     , NBLCK  , HTOPO  , TTOPO  , ILIM   , JLIM      RDCI
     4,         KLIM    , II     , JJ     , KK     , XP     , YP        RDCI
     5,         ZP      , FMAS   , TP     , PS     , VX     , VY        RDCI
     6,         VZ      , IL     , JL     , IBADD  , WGRINT , NSTRAT    RDCI
     7,         WLLX    , WLLY   , WURX   , WURY   , BOTHIT , IPARIN    RDCI
     8,         IOTOPO  , IOWIND , IHTOPO , IPOUT  , IPAROT , JTOP1     RDCI
     9,         JWIND1  , IRROR  , TLIMIT , ENDTIM , IC     , IBYPAS    RDCI
     1,         JTOPJ   , NLOST  , N3     , NTO    , NTI    , NW        RDCI
     2,         NALOFT  , JTIME1 , N3MAX  , NFREE  , N      , NCL       RDCI
     3,         CRMAXY  , CROHT  , NCRTYP , BZ     , CRMINX , CRMINY    RDCI
     4,         UU      , SN     , CS     , NLOCIR , DTLOC  , ATEMP     RDCI
     5,         RHO     , NA     , TGZ    , DTMAC  , PROG   , CRMAXX    RDCI
     6,         ROPART                                                  RDCI
      DIMENSION TOPOLM(4,4)     ,NINTAR(4)       ,ITOPLM(3,4)           RDCI
      DIMENSION S(10,10)        ,SUBSID(400)     ,IC(18)                RDCI
      DIMENSION XP(200)         ,YP(200)         ,ZP(200)        ,FMAS(200)  RDCI
      DIMENSION TP(200)         ,PS(200)         ,ATEMP(260)     ,RHO(260)   RDCI
      DIMENSION VX(1500)        ,VY(1500)        ,VZ(1500)       ,IL(70)     RDCI
      DIMENSION JL(70)          ,IBADD(70)       ,WURX(70)              RDCI
      DIMENSION WGRINT(70)                       ,WLLX(70)       ,WLLY(70)   RDCI
      DIMENSION WURY(70)        ,BOTHIT(70)      ,SN(6)          ,CS(6)      RDCI
      DIMENSION CRMINX(6)       ,CRMAXX(6)       ,CRMINY(6)      ,CRMAXY(6)  RDCI
      DIMENSION CROHT(6)        ,NCRTYP(6)       ,UU(6)                 RDCI
C                                                                       RDCI
C ********************************************************************RDCI
C                                                                       RDCI
    1 FORMAT(4E12.5,I3)                                                 RDCI
    2 FORMAT(///15X,22HLOCAL CIRCULATION CODEI4,18H IS NOT AVAILABLE.)  RDCI
C                                                                       RDCI
C ********************************************************************RDCI
C                                                                       RDCI
      DATA PROGRM /6HRDCIRS/                                            RDCI
C                                                                       RDCI
```

```
C ***********************************************************************RDCI   61
C ***********************************************************************RDCI   62
C                                                                         RDCI   63
C      READ DEFINING DATA FOR LOCAL CIRCULATION SYSTEMS                   RDCI   64
C                                                                         RDCI   65
       K=0                                                                RDCI   66
 120   K=K+1                                                              RDCI   67
       READ (ISIN,1) CRMINX(K),CRMAXX(K),CRMINY(K),CRMAXY(K), NCRTYP(K)   RDCI   68
       NCIR=NCRTYP(K)                                                     RDCI   69
       IF(NCIR)122,100,125                                                RDCI   70
 122   IRROR=122                                                          RDCI   71
       GO TO 7734                                                         RDCI   72
 125   IF(NCIR-5)120,120,124                                              RDCI   73
 124   IRROR=124                                                          RDCI   74
       WRITE (ISOUT,2)NCIR                                                RDCI   75
 7734  CALL ERROR(PROGRM,IRROR,ISOUT)                                     RDCI   76
C 100  THIS IS THE NORMAL EXIT                                            RDCI   77
C      NLOCIR     THE NUMBER OF LOCAL CIRCULATION SYSTEMS DEFINED FOR USERDCI   78
C                 IN TRANSPORTING PARTICLES                               RDCI   79
       RETURN                                                             RDCI   81
 100   NLOCIR = K-1                                                       RDCI   80
       END                                                                RDCI   82
                                                                                     83*

                                                                                     83 *
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```
$IBFTC MKWIN2  LIST,DECK,M94/2
      SUBRØUTINE MKWIND
C     28 NØVEMBER 1966
C     T. W. SCHWENKE   TECHNICAL ØPERATIØNS RESEARCH    SR  MKWIND  MK2
C
C ***********************************************************************
C
C     THIS SUBRØUTINE FØRMS A HØRIZØNTALLY AND VERTICALLY VARIANT WIND
C     DESCRIPTIØN IN CØRE ØN THE BASIS ØF INPUTS FRØM THE SYSTEM INPUT
C     TAPE.  INPUTS ARE AS FØLLØWS..
C       1  CØNTRØL VARIABLES ENDTIM ,    WHICH GIVES THE TIME AT WHICH
C        THE FØLLØWING DATA CEASE TØ BE VALID , ALPHA ,     WHICH IS A
C        WEIGHTING FACTØR TØ BE APPLIED TØ VERTICAL DISTANCES, BETA,
C        WHICH IS A WEIGHTING FACTØR TØ BE APPLIED TØ HØRIZØNTAL
C        DISTANCES, AND NN ,   WHICH SPECIFIES THE NUMBER ØF NEAREST
C        VECTØRS TØ BE USED IN ESTIMATING THE WIND VECTØR AT A GRID
C        PØINT.
C       2  WIND GRID SPECIFICATIØNS IN THE FØRM BØTHIT(J),WGRINT(J),
C        WLLX(J),WLLY(J),WURX(J),WURY(J)        (6F10.3)
C        WHERE BØTHIT(J) IS THE HEIGHT ØF THE BØTTØM ØF THE J-TH ARRAY,
C        WGRINT(J) IS THE GRID INTERVAL TØ BE USED IN THE J-TH LAYER,
C        AND WLLX(J), WLLY(J),WURX(J),WURY(J) ARE LØWER LEFT CØRNER AND
C        UPPER RIGHT CØRNER LIMIT CØØRDINATES.
C       3  WIND VECTØR DATA IN THE FØRM (BØTHIT(J),ZS(J),XS(J),YS(J),
C         SX(J),SY(J),SZ(J)
C        (6F12.3) WHERE  ZS(J) IS THE HEIGHT ØF THE J-TH VECTØR,
C        +SX(J) IS THE EASTWARD PØINTING CØMPØNENT ØF THE J-TH VECTØR,
C        +SY(J) IS THE NØRTHWARD PØINTING CØMPØNENT ØF THE J-TH VECTØR,
C        +SZ(J) IS THE UPWARD CØMPØNENT ØF THE J-TH VECTØR, XS(J) IS THE
C        EAST-WEST CØØRDINATE ØF THE J-TH VECTØR, AND YS(J) IS THE
C        NØRTH-SØUTH CØØRDINATE ØF THE J-TH VECTØR.
C        THE  LAYER READING ØPERATIØN IS TERMINATED WHEN BØTHIT(J) =
C        999999. ØR MØRE IS ENCØUNTERED.  THE VECTØR READING ØPERATIØN
C        IS TERMINATED WHEN ZS(J)=999999.0 ØR MØRE IS ENCØUNTERED.
C     A WIND FIELD TAPE IS- NØT- WRITTEN BY THIS PRØGRAM.
C
C************************** GLØSSARY ************************************
C
C     ALPHA         A WEIGHTING FACTØR FØR THE VERTICAL DISTANCES
C     BETA          A WEIGHTING FACTØR FØR THE HØRIZØNTAL DISTANCES
C     BIG           AN ARBITRARILY LARGE NUMBER
C     DM            DISTANCE BETWEEN THE CURRENT GRID PØINT AND THE MØST
C                   REMØTE ØF THE NEAREST NN DATA PØINTS
C     D12(J)        SEE D22(J).    FØR Y-DIRECTIØN BUT UNWEIGHTED
C     D22(J)        SQUARE ØF WEIGHTED Z DISTANCE BETWEEN GRID PØINT AND
C                   THE J-TH DATA VECTØR
C     SML           AN ARBITRARILY SMALL NUMBER
C     ISIN          SYSTEM INPUT TAPE NUMBER
C     ISØUT         SYSTEM ØUTPUT TAPE NUMBER
C     JH            FINAL (HIGHER) X INDEX .    SEE JLL
C     JJM           NUMBER ØF X RØWS IN ØUTPUT GRID
C     JLL           INITIAL (LØWER) X-INDEX FØR PRINTING PLANE ØF THE
C                   WIND FIELD ARRAY
C     STØRS         THE NUMBER ØF WIND STRATA IN THE DESIRED WIND FIELD
C                   DESCRIPTIØN
C     STØRV         THE TØTAL NUMBER ØF WIND DATA PØINTS BEING USED
C     K             USED BY MKWIND AS A STRATUM INDEX  AT PRINTING TIME
C     KK            Y-DIRECTIØN INDEX AT PRINTING TIME
C     NAD(J)        INDICES ØF DISTANCES BETWEEN THE CURRENT GRID PØINT
C                   AND THE JTH DATA PØINT
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C       NADT           INDEX ØF THE NAD THAT CØNTAINS THE ADDRESS ØF THE D2   MKWI  60
C                      WHICH IS THE LARGEST ØF NEAREST NN DATA PØINTS         MKWI  61
C       NCØDE          IDENTIFICATIØN NUMBER FØR THE METHØD ØF CØMPUTATIØN TØ MKWI  62
C                      BE USED IN TRANSLATING THE WIND DATA INTØ THE WIND     MKWI  63
C                      ARRAYS                                                 MKWI  64
C       NN             THE NUMBER ØF NEAREST DATA VECTØRS THAT THE USER WISHESMKWI  65
C                      TØ BE USED IN CØMPUTATIØNS                             MKWI  66
C       T1             TEMPØRARY STØRAGE                                      MKWI  67
C       WG2            HALF ØF GRID INTERVAL WGRINT(JW)                       MKWI  68
C       XG             X CØØRDINATE ØF GRID PØINT                             MKWI  69
C       XLIM           AN X-DIRECTIØN LIMIT FØR TESTING FØR THE CØMPLETIØN ØF MKWI  70
C                      A RØW IN THE WIND FIELD ARRAY                          MKWI  71
C       YG             .Y CØØRDINATE ØF GRID PØINT                            MKWI  72
C       YLIM           SEE XLIM.   FØR THE Y-DIRECTIØN                        MKWI  73
C       ZG             Z CØØRDINATE ØF GRID PØINT                             MKWI  74
C                                                                             MKWI  75
C*****************************************************************************MKWI  76
C                                                                             MKWI  77
      CØMMØN /SET1/                                                           MKWI  78
     1          DIAM    , DETID   , IRIDE   , IEXEC   , ISIN    , ISØUT   ,   MKWI  79
     2          SD      , SPAR    , SSAM    , TME     , TMP1    , TMP2    ,   MKWI  80
     3          T2M     , U       , VPR     , W       , X       , Z       ,   MKWI  81
     4          WHY     , RMIN    , IDISTR  , SPAR1   , SPAR2   , SPAR3   ,   MKWI  82
     5          SPAR4   , SPAR5   , SPAR6   , SPAR7   , SPAR8   , SPAR9       MKWI  83
      DIMENSIØN  DETID(12),WHY(40)                                            MKWI  84
      CØMMØN /SET2/                                                           MKWI  85
     1          S       , SUBSID  , GRINT   , BXLL    , BXLU    , BYLL        MKWI  86
     2,         BYLU    , TXLL    , TXLU    , TYLL    , TYLU    , XGZ         MKWI  87
     3,         YGZ     , NSLCK   , HTØP2   , TTØP2   , ILIM    , JLIM        MKWI  88
     4,         XLIM    , II      , JJ      , KK      , XP      , YP          MKWI  89
     5,         ZP      , FMAS    , TP      , PS      , VX      , VY          MKWI  90
     6,         VZ      , IL      , JL      , IBADD   , WGRINT  , NSTRAT      MKWI  91
     7,         WLLX    , WLLY    , WURX    , WURY    , BØTHIT  , IPARIN      MKWI  92
     8,         IØTØP2  , IØWIND  , IHTØP2  , IPØUT   , IPARØT  , JTØP1       MKWI  93
     9,         JWIND1  , IRRØR   , TLIMIT  , ENDTIM  , IC      , ICYPAS      MKWI  94
     1,         JTØPJ   , NLØST   , NG      , NT2     , NT1     , NN          MKWI  95
     2,         NALØFT  , JTIME1  , NBMAX   , NFREE   , N       , NCL         MKWI  96
     3,         CRMAXY  , CRUHT   , NCRTYP  , SZ      , CRMINX  , CRMINY      MKWI  97
     4,         UZ      , SN      , CS      , NLØCIR  , DTLØC   , ATEMP       MKWI  98
     5,         RHØ     , NA      , TGZ     , DTMAC   , FRØG    , CRMAXX      MKWI  99
     6,         RØPART                                                        MKWI 100
      DIMENSIØN TØPØLM(4,4)    ,NINTAR(4)      ,ITØPLM(3,4)                   MKWI 101
      DIMENSIØN S(10,10)       ,SUBSID(400)    ,IC(18)                        MKWI 102
      DIMENSIØN XP(200)        ,YP(200)        ,ZP(200)        ,FMAS(200)     MKWI 103
      DIMENSIØN TP(200)        ,PS(200)        ,ATEMP(260)     ,RHØ(260)      MKWI 104
      DIMENSIØN VX(1500)       ,VY(1500)       ,VZ(1500)       ,IL(70)        MKWI 105
      DIMENSIØN JL(70)         ,IBADD(70)      ,WURX(70)                      MKWI 106
      DIMENSIØN WGRINT(70)                     ,WLLX(70)       ,WLLY(70)      MKWI 107
      DIMENSIØN WURY(70)       ,BØTHIT(70)     ,SN(6)          ,CS(6)         MKWI 108
      DIMENSIØN CRMINX(6)      ,CRMAXX(6)      ,CRMINY(6)      ,CRMAXY(6)     MKWI 109
      DIMENSIØN CRUHT(6)       ,NCRTYP(6)      ,UØ(6)                         MKWI 110
C     PARAMETERS PECULIAR TØ MKWIND MK2                                       MKWI 111
      DIMENSIØN XS(300),YS(300),DX(300),DY(300),DZ(300),ZS(300),              MKWI 112
     1DZ2(300),DY2(300),D2(300),NAD(300)                                      MKWI 113
C                                                                             MKWI 114
C ****************************************************************************MKWI 115
C                                                                             MKWI 116
 1    FØRMAT(6F10.3)                                                          MKWI 117
 2    FØRMAT(//78HOTHE FØLLØWING WIND VECTØRS HAVE BEEN USED TØ DEFINE AMKWI 118
     1N ATMØSPHERE UP TØ TIME F10.0)                                          MKWI 119
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3     FØRMAT(/7X6HVECTØR7X22HHØRIZØNTAL CØØRDINATES8X17HVECTØR CØMPØNENT
     1S/7X6HHEIGHT10X2HXS10X2HYS10X2HVX10X2HVY10X2HVZ)
4     FØRMAT(4X,6F12.3)
5     FØRMAT(/62H  INADEQUATE CØNTRØL DATA.  CØMPUTATIØN METHØD 1 WILL B
     1E USED.)
6     FØRMAT(64H ENCØUNTERED TWØ WIND GRID LAYER REQUESTS FØR THE SAME A
     1LTITUDE.)
8     FØRMAT(5I4)
9     FØRMAT(19HCCØMPUTATIØN METHØD,I4,17H IS NØT AVAILABLE)
10    FØRMAT(/10X26HREQUESTED GRID ARRANGEMENT/7X6HHEIGHT9X8HINTERVAL22X
     16HLIMITS/33X4HWLLX8X4HWLLY8X4HWURX8X4HWURY/(4X6F12.3))
11    FØRMAT(16H1WIND CØMPØNENTS)
12    FØRMAT(1X,13HEAST-WEST RØW,I6)
13    FØRMAT(1X,10F12.5)
14    FØRMAT(19H0CØMPUTATIØN METHØDI6,17H WAS USED ØN THE I6,21H NEAREST
     1 DATA PØINTS.)
15    FØRMAT(//6H LEVELI3,6X,8HBASE AT ,F12.3,7H METERS)
16    FØRMAT(/19H NN WAS REDUCED TØ 15)
17    FØRMAT(6F12.3)
22    FØRMAT(6E20.8)
23    FØRMAT(  / 119H AN EXCESSIVE NUMBER ØF SIGNIFICANT FIGURES ARE LØS
     1T IN THE LEAST SQUARES CALCULATIØN.  THE DATA PØINTS APPRØACH A LI
     2NE/63H ØR A PLANE.  THE WEIGHTED VECTØR METHØD IS USED FØR GRID PØ
     3INT, 5X, 9H(X,Y,Z)=(, F12.3,1H,,F12.3,1H,,F12.3,1H))
24    FØRMAT(// 76H NØ VECTØRS LIE WITHIN THE SPECIFIED WEIGHTING REGIØN
     1.  A RANDØM SELECTIØN ØF ,I4, 30H VECTØRS ARE EQUALLY WEIGHTED ,
     2/ 5X, 15H FØR GRID PØINT,
     3      5X, 9H(X,Y,Z)=(, F12.3,1H,,F12.3,1H,,F12.3,1H))
25    FØRMAT ( // 10X,8HALPHA = F14.3, 7HMETERS,15X 7HDELTA = F14.3,
     1  7HMETERS.  )
C
C *****************************************************************
C
      DATA PRØGRM,BIG,NWIND,NWTST,GIS /6HMKWIND,1.0E+30,1500,0,1.0E-30/
C
C *****************************************************************
C *****************************************************************
C
      READ (ISIN,1)ENDTIM,ALPHA,BETA
      ALPHA2=ALPHA*ALPHA
      BETA2=BETA*BETA
C     READ SPECIFICATIØN ØF DESIRED WIND ARRAY PRØPERTIES
      READ (ISIN,8)NN,NCØDE
      IF(NN)204,204,2041
 204  IRRØR=204
 7734 CALL ERRØR(PRØGRM,IRRØR,ISØUT)
 2041 DØ 104 J=1,NSTRAT
      READ (ISIN,1) BØTHIT(J), AGRINT(J),WLLX(J),WLLY(J),WURX(J),WURY(J)
      IF(BØTHIT(J)-999999.0)104,105,105
 104  CØNTINUE
      IRRØR=104
      CALL ERRØR(PRØGRM,IRRØR,ISØUT)
 1041 READ(ISIN,1)XST
      IF(XST-999999.0)1041,105,105
 105  JTØPJ=J-1
C
C     NØW SØRT
 1054 KS=0
      DØ 1051 J=2,JTØPJ
      IF(BØTHIT(J)-BØTHIT(J-1))1153,1052,1051
 1153 KS=1
      HTST=BØTHIT(J-1)
      VXT=WGRINT(J-1)
      VYT=WLLX(J-1)
      VZT=WLLY(J-1)
      XST=WURX(J-1)
      YST=WURY(J-1)
      BØTHIT(J-1)=BØTHIT(J)
      WGRINT(J-1)=WGRINT(J)
      WLLX(J-1)=WLLX(J)
      WLLY(J-1)=WLLY(J)
      WURX(J-1)=WURX(J)
      WURY(J-1)=WURY(J)
      BØTHIT(J)=HTST
      WGRINT(J)=VXT
      WLLX(J)=VYT
      WLLY(J)=VZT
      WURX(J)=XST
      WURY(J)=YST
 1051 CØNTINUE
      IF(KS)1054,1055,1054
 1052 WRITE (ISØUT,6)
      IRRØR=1052
      GØ TØ 7734
C
C 1055   SØRT ØF THE REQUESTED LAYERS IS CØMPLETE
C        NØW MAKE SURE THAT THERE IS SUFFICIENT SPACE FØR THE WIND FIELD
 1055 DØ 1056 J=1,JTØPJ
      K1=(WURX(J)-WLLX(J))/WGRINT(J)+1.0
      K2=(WURY(J)-WLLY(J))/WGRINT(J)+1.0
 1056 NWTST=NWTST+K1*K2
C
C       IS AVAILABLE WIND MEMØRY EXCEEDED
      IF(NWIND .GT. NWTST) GØ TØ 1057
 1058 IRRØR=-1058
      GØ TØ 7734
 1057 DØ 100 J=1,500
      READ (ISIN,17)ZS(J),XS(J),YS(J),SX(J),SY(J),SZ(J)
      IF(ZS(J)-999999.0)100,101,101
 101  JTØPV=J-1
      IF(NN-JTØPV)106,106,2051
 2051 NN=JTØPV
      WRITE (ISØUT,16)JTØPV
      GØ TØ 106
 100  CØNTINUE
      IRRØR=100
      GØ TØ 7734
C
C                    VECTØR DATA ARE IN WIND ARRAYS ØN INDICES J=1,JTØPV
C     FIRST USE NCØDE AS A METHØD CØNTRØL VARIABLE.  BRANCH ØN NCØDE VIA
C     A CØMPUTED GØ TØ TØ THE DESIRED CØMPUTATIØN METHØD CØDE.
 106  NN1=NN+1
      IF(NCØDE)110,110,112
 112  IF(NCØDE-6)113,113,110
C
C 110  NCØDE IS INCØRRECT
 110  WRITE (ISØUT,5)
      NCØDE=1
 113  GØ TØ (115,116,117,118,119,120),NCØDE
C
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C 115 METHØD 1 USES THE NN NEAREST DATA PØINTS.  METHØDS 2,3 AND 4 ALSØ MKWI 240
C     USE THIS CØDE BUT FØR METHØD 2, NN=1 AND FØR METHØD 3, NN=JTØPV.  MKWI 241
C     FØR METHØD 4, THE NN SPECIFIED BY THE USER IS USED IN THE         MKWI 242
C     LEAST SQUARES METHØD(NN MUST BE GREATER THAN THREE).              MKWI 243
 115  IBADD(1)=1                                                        MKWI 244
      K=0                                                               MKWI 245
      JW=1                                                              MKWI 246
C                                                                       MKWI 247
C     NØW FILL IN THE WIND GRID SIZE WØRDS                              MKWI 248
 1151 IL(JW)=((WØRX(JW)-WLLX(JW)))/WGRINT(JW)   +.9999999               MKWI 249
      JL(JW)=((WØRY(JW)-WLLY(JW)))/WGRINT(JW) +.9999999                 MKWI 250
C                                                                       MKWI 251
C     NØW INITIALIZE FØR FILLING IN THE WIND GRID                       MKWI 252
      WG2=WGRINT(JW)/2.0                                                MKWI 253
      LX=1                                                              MKWI 254
      LY=1                                                              MKWI 255
      XG=WLLX(JW)+WG2                                                   MKWI 256
      YG=WLLY(JW)+WG2                                                   MKWI 257
      IF(JW-JTØPJ)1154,1155,1159                                        MKWI 258
 1159 IRRØR=1159                                                        MKWI 259
      GØ TØ 7734                                                        MKWI 260
 1155 IF(JW-1)1156,1156,1157                                            MKWI 261
 1156 ZG=BØTHIT(JW)                                                     MKWI 262
      GØ TØ 1158                                                        MKWI 263
 1157 ZG=ZG+BØTHIT(JW)-BØTHIT(JW-1)                                     MKWI 264
      GØ TØ 1158                                                        MKWI 265
 1154 ZG=(BØTHIT(JW)+BØTHIT(JW+1))/2.0                                  MKWI 266
C                                                                       MKWI 267
C     SET ALL NAD(J) EQUAL TØ J TØ PRØVIDE INDICES FØR THE FULL SET ØF  MKWI 268
C     DATA PØINTS AND TØ PRØVIDE AN INITIAL SET ØF -NEAREST- DATA PØINTSMKWI 269
C     SET NADT=1 TØ BEGIN THE SØRT PRØCEDURE THAT SELECTS THE MØST      MKWI 270
C     REMØTE ØF THE SET ØF -NEAREST- DATA PØINTS.  NØTE THAT FØR THE 1STMKWI 271
C     PASS ALL THE NN -NEAREST- PØINTS ARE EQUALLY LIKELY TØ BE THE MØSTMKWI 272
C     REMØTE ØF THE SET.                                                MKWI 273
 1158 DØ 203 J=1,JTØPV                                                  MKWI 274
 203  NAD(J)=J                                                          MKWI 275
      NADT=1                                                            MKWI 276
C                                                                       MKWI 277
C     CØMPUTE DISTANCES BETWEEN THE CURRENT GRID PØINT (XG,YG,ZG) AND   MKWI 278
C     EACH ØF THE DATA VECTØR LØCATIØNS                                 MKWI 279
C                                                                       MKWI 280
C     CØMPUTE SQUARED Z DELTAS                                          MKWI 281
      DØ 199 J=1,JTØPV                                                  MKWI 282
      TI=(ZS(J)-ZG)                                                     MKWI 283
      T1=T1*T1                                                          MKWI 284
      T2=(ALPHA2-T1)                                                    MKWI 285
      IF(T2.LT.0.0)  T2=0.0                                             MKWI 286
 199  DZ2(J)=T2/(ALPHA2+T1)                                             MKWI 287
C                                                                       MKWI 288
C     CØMPUTE SQUARED Y DELTAS                                          MKWI 289
 200  DØ 201 J=1,JTØPV                                                  MKWI 290
      T1=YS(J)-YG                                                       MKWI 291
 201  DY2(J)=T1*T1                                                      MKWI 292
C                                                                       MKWI 293
C     CØMPUTE SQUARED DISTANCES                                         MKWI 294
 2011 DØ 202 J=1,JTØPV                                                  MKWI 295
      T1=(XS(J)-XG)*(XS(J)-XG)+DY2(J)                                   MKWI 296
      T2=((BETA2-T1)/(BETA2+T1))*DZ2(J)                                 MKWI 297
      IF(T2-GIG) 2021,2021,2022                                         MKWI 298
 2021 D2(J)=GIG                                                         MKWI 299
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```
      GØ TØ 202
 2022 D2(J)=1.0/T2
 202  CØNTINUE
C
C     FIND THE ADDRESS ØF AND DISTANCE TØ THE MØST REMØTE PØINT ØF THE
C     NN -NEAREST- PØINTS (THE PØINTS WHØSE ADDRESSES ARE GIVEN BY
C     NAD(1),NAD(NN).) STØRE THAT MAXIMUM DISTANCE IN THE WØRD DM AND
C     SET NADT SUCH THAT DM=D2(NAD(NADT)).
      KL=NAD(NADT)
      DM=D2(KL)
      DØ 207 J=1,NN
      KL=NAD(J)
      IF(DM-D2(KL))208,207,207
 208  DM=D2(KL)
      NADT=J
 207  CØNTINUE
C     AT THIS PØINT, DM IS THE LARGEST D2(J) FØR J=NAD(J),NAD(NN)
C
      IF (NN1-JTØPV)2072,2072,2073
C
C2072 NØW SELECT BEST NN PØINTS
C     SCAN THE SET D2(J),J=NAD(NN+1,JTØPV) UNTIL A D2(J) LESS THAN DM
C     IS FØUND.  IF ØNE IS FØUND, SWITCH NAD(NADT) WITH THE SELECTED NAD
C     THEN RESET DM AND NADT TØ INDICATE THE MØST REMØTE ØF THE NEAREST
C     NN PØINTS.  WHEN THE FULL SET D2(J),J=NAD(NN+1,JTØPV) HAS BEEN
C     SCANNED, THE SET ØF NEAREST DATA PØINTS HAS BEEN SELECTED.  ØNLY
C     ØNE SCAN IS REQUIRED.
 2072 DØ 210 J=NN1,JTØPV
      KL=NAD(J)
      IF(DM-D2(KL))210,210,211
 211  NTEMP=NAD(J)
      NAD(J)=NAD(NADT)
      NAD(NADT)=NTEMP
C
C     NØW RESET DM AND NADT TØ THE NEW MØST REMØTE PØINT
      DM=D2(KL)
      DØ 212 KKK=1,NN
      KL=NAD(KKK)
      IF(DM-D2(KL))213,212,212
 213  DM=D2(KL)
      NADT=KKK
C
C     DM AND NADT ARE SET WITH THE PARAMETERS ØF THE MØST REMØTE ØF
C     THE NEAREST NN PØINTS
 212  CØNTINUE
 210  CØNTINUE
 2073 CØNTINUE
C
C     THE NEAREST NN HAVE BEEN FØUND
C     *********SØME DAY INSERT HERE A BRANCH TØ A WEIGHTING METHØD HERE**
C
C     INCREMENT INDEX FØR STØRING VECTØR CØMPUTED FØR PØINT (XG,YG,ZG)
      K=K+1
C
C     IS THE LEAST SQUARES METHØD TØ BE USED.  YES TØ 2081
      IF(NCØDE-4)2080,2081,2080
C
C2081 THIS IS THE LEAST SQUARES METHØD
C     INITIALIZE FØR LEAST SQUARES METHØD
 2081 SNN=NN
```

```
      SDX=0.0
      SDY=0.0
      SDZ=0.0
      SDX2=0.0
      SDY2=0.0
      SDZ2=0.0
      SDXY=0.0
      SDXZ=0.0
      SDYZ=0.0
      SAU=0.0
      SAV=0.0
      SAW=0.0
      SUX=0.0
      SUY=0.0
      SUZ=0.0
      SVX=0.0
      SVY=0.0
      SVZ=0.0
      SWX=0.0
      SWY=0.0
      SWZ=0.0
C
C     BEGIN LØØP TØ EVALUATE INTERMEDIATE STEP FØR LEAST SQUARES CALC.
      DØ 3100 J=1,NN
      KL=NAD(J)
C
C      CØMPUTE DISTANCE BETWEEN KL-TH DATA PØINT AND CURRENT GRID PØINT
      T1=XS(KL)-XG
      TY=YS(KL)-YG
      TZ=ZS(KL)-ZG
C
C     CØMPUTE ELEMENTS ØF LEAST SQUARES MATRIX, B
      SDX=SDX+T1
      SDY=SDY+TY
      SDZ=SDZ+TZ
      SDX2=SDX2+T1*T1
      SDY2=SDY2+DY2(KL)
      SDZ2=SDZ2+DZ2(KL)
      SDXY=SDXY+T1*TY
      SDXZ=SDXZ+T1*TZ
      SDYZ=SDYZ+TY*TZ
      SAU=SAU+UX(KL)
      SAV=SAV+UY(KL)
      SAW=SAW+UZ(KL)
      SUX=SUX+T1*UX(KL)
      SUY=SUY+TY*UX(KL)
      SUZ=SUZ+TZ*UX(KL)
      SVX=SVX+T1*UY(KL)
      SVY=SVY+TY*UY(KL)
      SVZ=SVZ+TZ*UY(KL)
      SWX=SWX+T1*UZ(KL)
      SWY=SWY+TY*UZ(KL)
 3100 SWZ=SWZ+TZ*UZ(KL)
      SAUG1=SDY2*SDZ2-SDYZ*SDYZ
      SAUG2=SDXY*SDZ2-SDYZ*SDXZ
      SAUG3=SDXY*SDYZ-SDY2*SDXZ
      SAUG4=SDX2*SDY2-SDXY*SDXY
C
C     CØMPUTE CØMPLEMENTARY MINØRS ØF MATRIX B
      B11=SDX2*SAUG1-SDXY*SAUG2+SDXZ*SAUG3
      B21=SDX*SAUG1-SDY*SAUG2+SDZ*SAUG3
      B31=SDX*SAUG2-SDY*(SDX2*SDZ2-SDXZ*SDXZ)+SDZ*SAUG4
      B41=SDX*SAUG3-SDY*SAUG4+SDZ*(SDX2*SDY2-SDXY*SDXY)
C
C       TEST TØ SEE IF A RØW ØR CØLUMN IS APPRØXIMATELY ZERØ
      BB= AMAX1(ABS(SNN*B11),ABS(SDX*B21),ABS(SDY*B31), ABS(SDZ*B41))
      IF(BB-1.0E-20)3800,3800,3700
C
C     CØMPUTE DETERMINANT ØF B
 3700 BBB=SNN*B11-SDX*B21+SDY*B31-SDZ*B41
C
C     TEST FØR LØSS ØF PRECISIØN
      IF(ABS(BBB/BB)-0.001)3800,3800,3900
C
C3800 TØØ MANY SIGNIFICANT FIGURES ARE LØST IN THE LEAST SQUARES
C     CALCULATIØN.  THE DATA PØINTS APPRØACH A PØINT, A LINE, ØR A
C     PLANE.  USE THE WEIGHTED VECTØR METHØD
 3800 WRITE (ISØUT,23)XG,YG,ZG
      GØ TØ 2080
C
C     CØMPUTE WIND VECTØRS
 3900 VX(K)=(B11*SAU-B21*SUX+B31*SUY-B41*SUZ)/BBB
      VY(K)=(B11*SAV-B21*SVX+B31*SVY-B41*SVZ)/BBB
      VZ(K)=(B11*SAW-B21*SWX+B31*SWY-B41*SWZ)/BBB
      GØ TØ 2090
C
C2080 CØMPUTE AND SUM  THE WEIGHTING FACTØRS
 2080 SUM=0.0
      DØ 214 J=1,NN
      L=NAD(J)
 2142 D2(L)=1.0/D2(L)
 214  SUM=SUM+D2(L)
      IF(SUM/FLØAT(NN) .LE. GIB) WRITE(ISØUT,24) NN,XG,YG,ZG
C
C     NØW CØMPUTE VECTØR ESTIMATE AT GRID PØINT
C     CØMPUTE STØRAGE INDEX
C     CØMPUTE AND STØRE WIND ESTIMATE AT GRID PØINT
      VX(K)=0.0
      VY(K)=0.0
      VZ(K)=0.0
      DØ 216 J=1,NN
      L=NAD(J)
      VX(K)=VX(K)+SX(L)*D2(L)
      VY(K)=VY(K)+SY(L)*D2(L)
 216  VZ(K)=VZ(K)+SZ(L)*D2(L)
      VX(K)=VX(K)/SUM
      VY(K)=VY(K)/SUM
      VZ(K)=VZ(K)/SUM
 2090 XG=XG+WGRINT(JW)
      LX=LX+1
      IF(LX-IL(JW))2011,2011,2012
 2012 XG=WLLX(JW)+WG2
      LY=LY+1
      LX=1
      YG=YG+WGRINT(JW)
      IF(LY-JL(JW))200, 200,1152
 1152 JW=JW+1
      IF(JW-JTØPJ)1160,1160,150
 1160 JT=JW-1
      IBADD(JW)=IBADD(JT)+(IL(JT))*(JL(JT))
      GO TO 1151
C
C 116  METHOD 2   NEAREST VECTOR
 116  NN=1
      GO TO 115
C
C 117  METHOD 3    ALL VECTORS WEIGHTED
 117  NN=JTOPV
      GO TO 115
 118  CONTINUE
C
C 118  METHOD 4   LEAST SQUARES
C      USE BRANCH ON NCODE=4 TO BRANCH TO LEAST SQUARES IN CODE
C      NN MUST BE GREATER THAN 3 FOR THE LEAST SQUARES METHOD
 1180 IF(NN-4)1181,115,115
 1181 IRROR=1181
      GO TO 7734
 119  CONTINUE
 120  CONTINUE
 121  WRITE (ISOUT,9)NCODE
      IRROR=121
      GO TO 7734
 130  WRITE (ISOUT,2)ENDTIM
      WRITE (ISOUT,3)
      WRITE (ISOUT,4)(ZS(J),XS(J),YS(J),SX(J),SY(J),SZ(J),J=1,JTOPV)
      WRITE (ISOUT,10)(WGTHIT(J),WGHINT(J),WLLX(J), WLLY(J),WURX(J),WURY
     1(J),J=1,JTOPV)
      WRITE (ISOUT,14)NCODE,NN
      WRITE (ISOUT,20)  ALPHA, WIDTH
      IF(IO(7)-1)109,1091,109
 1091 WRITE (ISOUT,11)
      DO 107 K=1,JTOPV
      WRITE (ISOUT,15)K,WGTHIT(K)
      JJH=JL(K)
      JLL=IJADD(K)
      DO 108 KK=1,JJH
      JH=JLL+IL(K)-1
      WRITE (ISOUT,12)KK
      WRITE (ISOUT,13)(VX(J),J=JLL,JH)
      WRITE (ISOUT,13)(VY(J),J=JLL,JH)
      WRITE (ISOUT,13)(VZ(J),J=JLL,JH)
      JLL=JH+1
 108  CONTINUE
 107  CONTINUE
 109  CALL RSCIRC
      RETURN
      END
```

```
$IBFTC LIN7     LIST,DECK,M94/2                                                 LIN7
      SUBROUTINE LINK7                                                          LIN7
C           T.W.SCHWENKE  TECHNICAL OPERATIONS RESEARCH            LINK 7       LIN7
C     19 OCT 66                                                                 LIN7
C       THIRD PART OF TRANSPORT MODULE.  PARTICLE TRANSPORT.                    LIN7
C                                                                               LIN7
C **********************************************************************LIN7
C                                                                               LIN7
C     SEE SUBROUTINE LINK5 FOR A TRANSPORT GLOSSARY                             LIN7
C                                                                               LIN7
C **********************************************************************LIN7
C                                                                               LIN7
      COMMON /SET1/                                                             LIN7
     1        DIAM    ,DETID(12),IRISE   , IEXEC   , ISIN    , ISOUT    ,      LIN7
     2        SD      , SPAR    , SSAM    , TME     , TMP1    , TMP2     ,      LIN7
     3        T2M     , U       , VPR     , W       , X       , Z        ,      LIN7
     4        WHY(4 ), RMIN    , IDISTR  , SPAR1   , SPAR2   , JDONE    ,      LIN7
     5        SPAR4   , SPAR5   , SPAR6   , SPAR7   , SPAR8   , SPAR9           LIN7
C                                                                               LIN7
C **********************************************************************LIN7
C                                                                               LIN7
      COMMON /SET2/                                                             LIN7
     1        S       , SUBSID  , GRINT   , BXLL    , BXLU    , BYLL            LIN7
     2,       BYLU    , TXLL    , TXLU    , TYLL    , TYLU    , XGZ             LIN7
     3,       YGZ     , NBLCK   , HTOPO   , ITOPO   , ILIM    , JLIM            LIN7
     4,       KLIM    , II      , JJ      , KK      , XP      , YP              LIN7
     5,       ZP      , FMAS    , TP      , PS      , VX      , VY              LIN7
     6,       VZ      , IL      , JL      , IBADD   , WGRINT  , NSTRAT          LIN7
     7,       WLLX    , WLLY    , WURX    , WURY    , BOTHIT  , IPARIN          LIN7
     8,       IOTOPO  , IOWIND  , IHTOPO  , IPOUT   , IPAROT  , JTOP1           LIN7
     9,       JWIND1  , IRROR   , TLIMIT  , ENDTIM  , IC      , ISYPAS          LIN7
     1,       JTOPJ   , NLOST   , NG      , NTO     , NTI     , NW              LIN7
     2,       NALOFT  , JTIME1  , NBMAX   , NFREE   , N       , NCL             LIN7
     3,       CRMAXY  , CROHT   , NCRTYP  , BZ      , CRMINX  , CRMINY          LIN7
     4,       OO      , SN      , CS      , NLOCIR  , DILOC   , ATEMP           LIN7
     5,       RHO     , NA      , TGZ     , DIMAC   , PROG    , CRMAXX          LIN7
     6,       ROPART                                                            LIN7
      DIMENSION TOPOLM(4,4)    ,NINTAR(4)      ,ITOPLM(3,4)                     LIN7
      DIMENSION S(10,10)       ,SUBSID(400)    ,IC(18)                          LIN7
      DIMENSION XP(200)        ,YP(200)        ,ZP(200)        ,FMAS(200)       LIN7
      DIMENSION TP(200)        ,PS(200)        ,ATEMP(260)     ,RHO(260)        LIN7
      DIMENSION VX(1500)       ,VY(1500)       ,VZ(1500)       ,IL(70)          LIN7
      DIMENSION JL(70)         ,IBADD(70)      ,WURX(70)                        LIN7
      DIMENSION WGRINT(70)                     ,WLLX(70)       ,WLLY(70)        LIN7
      DIMENSION WURY(70)       ,BOTHIT(70)     ,SN(6)          ,CS(6)           LIN7
      DIMENSION CRMINX(6)      ,CRMAXX(6)      ,CRMINY(6)      ,CRMAXY(6)       LIN7
      DIMENSION CROHT(6)       ,NCRTYP(6)      ,OO(6)                           LIN7
C                                                                               LIN7
C **********************************************************************LIN7
C                                                                               LIN7
 1    FORMAT(3I5,6E12.5)                                                        LIN7
 10   FORMAT (I5)                                                               LIN7
 11   FORMAT(6E15.5)                                                            LIN7
 12   FORMAT(5E15.5,6I5)                                                        LIN7
C                                                                               LIN7
C **********************************************************************LIN7
C                                                                               LIN7
      DATA PROGRM /6HLINK7 /                                                    LIN7
C                                                                               LIN7
C **********************************************************************LIN7
C **********************************************************************LIN7
```

```
C
      JW=0
      NUL=0
      EPSIL=1.0
C
C     ARE TRANSPORT TRACES TO BE WRITTEN..  YES TO 5500
      IF(IC(6)-1)5510,5510,5500
 5500 MPNT=2
      GO TO 5520
 5510 MPNT =1
C
C     BRANCH TO READ ADDITIONAL DATA
C     READ DATA PECULIAR TO EACH LOCAL WIND SYSTEM
 5520 IF(NLOCIR) 510,510,511
C
C 511 SETTING J NEGATIVE WILL CAUSE THE LOCAL CIRCULATION SYSTEM CODES
C     TO READ THE DATA THAT THEY NEED WHEN THEY ARE FIRST ENTERED
 511  J=-1
      DO 500 I=1,NLOCIR
      K=I
      NCIR=NCRTYP(I)
      GO TO (501,502,503,504,505),NCIR
 501  CALL MTWND1(J,K,AX,AY,AZ)
      GO TO 500
 502  CALL RGWND1(J,K,AX,AY,AZ)
      GO TO 500
 503  CALL CBREZ1(J,K,AX,AY,AZ)
      GO TO 500
C ****************   CODE INSERTION POINTS   ****************************
 504  CONTINUE
 505  CONTINUE
C ****************   CODE INSERTION POINTS   ****************************
 506  IRROR=-506
      GO TO 500
 500  CONTINUE
C
 510  IF(TLIMIT-ENDTIM)48,49,49
 48   ENDTIM=TLIMIT
 49   IF(IC(1)-1)51,50,51
 50   ASSIGN 188 TO IT
      ASSIGN 188 TO ITT
      GO TO 1000
 51   ASSIGN 1871 TO IT
      ASSIGN 1813 TO ITT
 1000 IF=NALOFT
      IF(JTIME1)1113,1112,1112
 1113 JTIME1=0
      GO TO 1001
C
C     ATTEMPT TO READ IN A BLOCK OF PARTICLES ALOFT RECORDS
C     FIRST READ BLOCK SIZE
 1112 READ (IPARTM)N
C
C     IF BLOCK SIZE IS NEGATIVE OR ZERO, NO BLOCK EXISTS
      IF(N)100,100,101
C
C     CHECK TO SEE IF BLOCK WILL FIT IN ARRAY
 101  IF(N-NALOFT)1 21,1021,103
```

```
C
C103  ERROR - ALOFT LIST TOO LARGE. SHOULD NEVER HAPPEN. GO TO EXIT.
 103  IRROR=103
C
C300  GENERALIZED ERROR STOP
 300  CALL ERROR(PROGRM,IRROR,ISOUT)
C
 1021 CALL DUMPP
C
C 102 NOW READ A BLOCK OF PARTICLE ALOFT DESCRIPTIONS
 102  IF=N
      READ (IPARIN)(XP(J),YP(J),ZP(J),TP(J),PS(J),FMAS(J),J=1 ,IF)
C
C     ARE TRANSPORT TRACES TO BE WRITTEN..  YES TO 5522
      IF(IC(6))5521,5521,5522
 5522 WRITE (ISOUT,11)(XP(J),YP(J),ZP(J),TP(J),PS(J),FMAS(J),J=1,NALOFT)
 5521 NFREE=NFREE-N
C
C ********************************************************************
C
C     BEGINNING OF PARTICLES ALOFT LIST LOOP
 1001 DO 160 J=1,IF
      ASSIGN 3052 TO IPAS
      GO TO (5540,5530),MPNT
 5530 WRITE  (ISOUT,11) XP(J),YP(J),ZP(J),TP(J),PS(J),FMAS(J)
C
C     SELECT PARTICLE TO BE TRANSPORTED  --  +TP     +FMAS
 5540 IF(FMAS(J))160 ,160 ,192
 192  IF(TP(J))160,193,194
 194  IF(TP(J)-ENDTIM)195,160,1971
 1971 IF(TP(J)-TLIMIT)160,160,197
 193  IRROR=-193
      GO TO 300
 197  IRROR=-197
      GO TO 300
C
C 195  A PARTICLE HAS BEEN SELECTED
C     IS THE CURRENT PARTICLE WITHIN A LOCAL CIRCULATION SYSTEM
 195  IF(NLOCIR)1950,1950,1951
 1951 DO 1952 K=1,NLOCIR
C************************  TEMP   *************************************
      WRITE (ISOUT,1)J,K,NLOCIR,FMAS(J),XP(J),YP(J),ZP(J), TP(J)
      IF(XP(J)-CRMINX(K))1952,1953,1953
 1953 IF(CRMAXX(K)-XP(J))1952,1954,1954
 1954 IF(YP(J)-CRMINY(K))1952,1955,1955
 1955 IF(CRMAXY(K)-YP(J))1952,1956,1956
C
C 1956 THE JTH PARTICLE IS WITHIN THE KTH LOCAL CIRCULATION SYSTEM
C     SUBROUTINE LOTRAN(J,K) TRANSPORTS THE JTH PARTICLE IN THE KTH
C     LOCAL WIND SYSTEM.
 1956 CALL LOTRAN(J,K)
C
C     188 IS WHERE GROUNDED PARTICLES ARE DEALT WITH.
      IF(ZP(J)+9000.0)188,188,1957
 1957 IF(TP(J)-ENDTIM)1951,1958,1958
 1958 NTI=NTI+1
      GO TO 160
 1952 CONTINUE
```

```
C
 1950 XX=XP(J)
      YY=YP(J)
      ZZ=ZP(J)
      PSIZE=PS(J)
 1961 CALL GETWND(XX,YY,ZZ,JWAD,JW)
      IF(JWAD)1959,1960,196
C
C 1959 THE NEEDED WIND FIELD IS NOT IN CORE
 1959 FMAS(J)=-FMAS(J)
      TP(J)=TLIMIT
      NLOST=NLOST+1
      GO TO 160
 1960 IRROR=-1960
      GO TO 300
C
C 196 GET PARTICLE FALL RATE.  PUT IT IN FV WITH SIGN POSITIVE.
 196  CALL FALRAT(ZZ,PSIZE,FV,ATEMP,RHO,FROG,ISOUT)
C
C     COMPUTE VERTICAL PARTICLE MOTION COMPONENT
C     A POSITIVE VPZ DENOTES AN UPWARD POINTING VECTOR
      VPZ=VZ(JWAD)-FV
C
C     COMPUTE TIMES TO NEXT MACRO WIND FIELD BORDERS
C     COMPUTE TIX -- TRANSIT TIME TO X BOUNDARY
      XBL=(AINT((XP(J)-WLLX(JW))/WGRINT(JW)))*WGRINT(JW) +WLLX(JW)
      XBU=XBL+WGRINT(JW)
      YBL=(AINT((YP(J)-WLLY(JW))/WGRINT(JW)))*WGRINT(JW) +WLLY(JW)
      YBU=YBL+WGRINT(JW)
      ASSIGN 917 TO N1
      IF(VX(JWAD))161,162,163
 161  TIX=(XBL-XP(J))/(VX(JWAD))
      GOTO 164
 162  TIX=100000.0
      ASSIGN 918 TO N1
      GO TO 164
 163  TIX=(XBU-XP(J))/(VX(JWAD))
C
C     COMPUTE TIY -- TRANSIT TIME TO Y BOUNDARY
 164  ASSIGN 919 TO N2
      IF(VY(JWAD))165,166,167
 165  TIY=(YBL-YP(J))/(VY(JWAD))
      GO TO 168
 166  TIY=100000.0
      ASSIGN 920 TO N2
      GO TO 168
 167  TIY=(YBU-YP(J))/(\Y(JWAD))
C
C     COMPUTE TIZ -- TRANSIT TIME TO Z BOUNDARY
C 168 IS PARTICLE MOVING UP OR DOWN.   UP TO 171
 168  IF(VPZ)169,170,171
C
C 169 IS PARTICLE BELOW MAX TOPO HEIGHT.   YES TO 1691
 169  IF (ZP(J)-TTOPO)1691,1691,1693
C
C     1693 IS MAX TOPO HEIGHT ABOVE SLICE BOTTOM.  YES TO 1692
 1693 IF (TTOPO-BOTHIT(JW))1691,1691,1692
 1692 TIZ = (TTOPO-ZP(J))/VPZ
```

```
      GO TO 1711
 1691 TIZ=(BOTHIT(JW)-ZP(J))/VPZ
      GO TO 1711
 170  TIZ=100000.0
      GO TO 1711
 171  TIZ=(BOTHIT(JW+1)-ZP(J))/VPZ
C
C1711 FIND THE EARLIEST INTERSECTION WITH A LOCAL CIRCULATION SYSTEM
 1711 CIRMIN=TLIMIT
C     ARE THERE ANY LOCAL CIRCULATION SYSTEMS.   YES TO 1712
      IF(NLOCIR)172,172,1712
C
C 1712 COMPUTE TIME OF FLIGHT TO EACH OF THE FOUR VERTICAL PLANES THAT
C      BOUND THE LJ-TH LOCAL CIRCULATION CELL.
 1712 DO 1713 LJ=1,NLOCIR
      GO TO (917,918),N1
 918  TX1=1000000.0
      TX2=1000000.0
      GO TO 921
 917  TX1=(CRMINX(LJ)-XP(J))/VX(JWAD)
      TX2=(CRMAXX(LJ)-XP(J))/VX(JWAD)
 921  GO TO (919,920),N2
 920  TY1=1000000.0
      TY2=1000000.0
      GO TO 922
 919  TY1=(CRMINY(LJ)-YP(J))/VY(JWAD)
      TY2=(CRMAXY(LJ)-YP(J))/VY(JWAD)
C
C     TEST  X INTERCEPTS
C     IS THE FIRST X DIRECTION INTERCEPT IN TNE PAST.  YES TO 1714
 922  IF(TX1)1714,1716,1716
C
C 1714 IS THE SECOND X DIRECTION INTERCEPT ALSO IN THE PAST.  IF YES,
C      BOTH X DIRECTION INTERCEPTS ARE IN THE PAST AND THE PARTICLE WILL
C      NOT INTERSECT THIS CELL.  GO TO 1713 TO CONSIDER THE NEXT CELL.
 1714 IF(TX2)1713,1715,1715
 1715 TMINX=TX1
      TMAXX=TX2
      GO TO 1717
 1716 IF(TX2)1718,1719,1719
 1718 TMINX=TX2
      TMAXX=TX1
      GO TO 1717
C
C 1719 BOTH X INTERCEPTS ARE IN THE FUTURE
 1719 IF(TX1-TX2)1715,1715,1718
C
C 1717 NOW TEST FOR Y INTERCEPTS
 1717 IF(TY1)1720,1721,1721
 1720 IF(TY2)1713,1723,1723
 1723 TMINY=TY1
      TMAXY=TY2
      GO TO 1724
 1721 IF(TY2)1725,1726,1726
 1725 TMINY=TY2
      TMAXY=TY1
      GO TO 1724
C
```

```
C 1726 BOTH Y INTERCEPTS ARE IN THE FUTURE
 1726 IF(TY1-TY2)1723,1723,1725
C 1724 NOW SELECT FIRST INTERCEPT
C
C      SELECT THE SECOND PLANE PIERCE  (LAST OF FIRSTX,FIRSTY)
 1724 IF(TMINX-TMINY)1727,1728,1728
 1728 TS=TMINX
      TC=TMAXY
      GO TO 1729
 1727 TS=TMINY
      TC=TMAXX
 1729 IF(TS-TC)1730,1713,1713
C
C 1730 KEEP TIME OF EARLIEST INTERCEPT
 1730 IF(TS-CIRMIN)1731,1713,1713
 1731 CIRMIN=TS
 1713 CONTINUE
C******** * * * * * *    TEMP     * * * * * * *********
      WRITE (ISOUT,11)CIRMIN
C
C      AT THIS POINT CIRMIN CONTAINS THE TIME OF THE FIRST INTERCEPT
C      BETWEEN PARTICLE AND A LOCAL CIRCULATION SYSTEM
C 172 NOW SELECT EARLIEST BOUNDARY
 172  IF(TIX-TIY)173,175,175
 173  IF(TIX-TIZ)176,178,178
 176  TSM=TIX
      IR=1
      GO TO 179
C
C 178 SET SMALLEST TIME OF FLIGHT STORAGE AT THE TIME OF FLIGHT TO THE
C      Z BOUNDARY
 178  TSM=TIZ
      IR=3
      GO TO 179
 175  IF(TIY-TIZ)180,178,178
 180  TSM=TIY
      IR=2
C
C 179 IS INTERSECTION WITH LOCAL SYSTEM PRIOR TO EARLIEST BOUNDARY
C      INTERCEPT.    YES TO 1792
 179  IF(TSM-CIRMIN)1791,1793,1792
 1792 TSM=CIRMIN
 1793 IR=5
C
C 1791  DOES TIME LIMIT COME BEFORE EARLIEST OTHER BOUNDARY. YES TO 182
 1791 IF(TSM+TP(J)-ENDTIM)181,182,182
C
C 182  TRANSPORT PARTICLE UNTIL ENDTIM
 182  TSM=ENDTIM-TP(J)
      IR=4
      GO TO 3067'
C
C 181 TEST FOR EXCESSIVELY SMALL MOVEMENT
  181 GO TO(5580,5570),MPNT
 5570  WRITE (ISOUT,11) TSM,VPZT,VPZ,TIY,FV
 5580 IF(TSM-EPSIL)3050,3050,3067
C
C      SPECIAL TRANSPORT IN THE EVENT OF EXCESSIVELY SMALL TSM
```

```
 3050 GO TO IPAS,(3052,3053)
C
 3052 ASSIGN 3053 TO IPAS
      JWAD1=JWAD
      VPZT=VPZ
      TSM=EPSIL
      GO TO 1811
 3053 IF(VPZT*VPZ)3 54,3055,3055
 3054 VPZ=0.0
      TIZ=TLIMIT
      GO TO 3056
 3055 VPZ=(VPZ+VPZT)/2.0
C
C     IF VECTORS ARE OF OPPOSITE SIGNS, USE A ZERO
 3056 IF(VX(JWAD)*VX(JWAD1))3057,3058,3058
 3057 VPX=0.0
      TIX=TLIMIT
      GO TO 3059
 3058 VPX=(VX(JWAD)+VX(JWAD1))/2.0
C
 3059 IF(VY(JWAD)*VY(JWAD1))3060,3061,3061
 3060 VPY=0.0
      TIY=TLIMIT
      GO TO 3062
C
 3061 VPY=(VY(JWAD)+VY(JWAD1))/2.0
 3062 TWND=ENDTIM-TP(J)
      TSM=AMIN1(TIX,TIY,TIZ,CIRMIN,TWND)
      IF(TSM-TWND)3065,3064,3065
 3064 IR=4
      GO TO 3066
 3065 IR=5
      TSM=TSM+EPSIL
      TP(J)=TP(J)+TSM
C
 3066 XP(J)=XP(J)+VPX*TSM
      YP(J)=YP(J)+VPY*TSM
      ZP(J)=ZP(J)+VPZ*TSM
      GO TO 3063
 3067 ASSIGN 3052 TO IPAS
C
C 3051IS PARTICLE BELOW MAXIMUM TOPO HEIGHT     NO TO 1811
 3051 IF(ZP(J)-TTOPO)1812,1812,1811
 1812 GO TO ITT,(188,1813)
C
C 1813 TRANSPORT PARTICLE FOR TSM BY STEPS OF DTMAC CHECKING TOPO AS WE
C       GO
C     COMPUTE MOVEMENT INCREMENTS FOR X,Y, AND Z DIRECTIONS
 1813 XIN=DTMAC*VX(JWAD)
      YIN=DTMAC*VY(JWAD)
      ZIN=DTMAC*VPZ
 1814 XP(J)=XP(J)+XIN
      YP(J)=YP(J)+YIN
      ZP(J)=ZP(J)+ZIN
      TP(J)=TP(J)+DTMAC
      TSM=TSM-DTMAC
C
C     TEST FOR PARTICLE IMPACT ON TOPOGRAPHY
```

```
      X=XP(J)                                                           LIN7 409
      Y=YP(J)                                                           LIN7 410
      CALL HEIGHT(X,Y,H)                                                LIN7 411
      IF(H+20000.0)1872,1872,1815                                       LIN7 412
 1815 IF(H+10000.0)1875,1875,1816                                       LIN7 413
 1816 IF(H-ZP(J))1817,188,188                                           LIN7 414
 1817 IF(TSM)189,189,1814                                               LIN7 415
C                                                                       LIN7 416
C 1811 TRANSPORT PARTICLE FOR TSM                                       LIN7 417
C      FIRST INCREASE TSM TO ASSURE THAT THE PARTICLE WILL ACHIEVE ITS  LIN7 418
C      BOUNDARY                                                         LIN7 419
 1811 TSM=TSM*1.000 01                                                  LIN7 420
      XP(J)=XP(J)+VX(JWAD)*TSM                                          LIN7 421
      YP(J)=YP(J)+VY(JWAD)*TSM                                          LIN7 422
      ZP(J)=ZP(J)+VPZ*TSM                                               LIN7 423
      TP(J)=TP(J)+TSM  "                                                LIN7 424
 3063 CONTINUE                                                          LIN7 425
C                                                                       LIN7 426
C      ARE TRANSPORT TRACES TO BE WRITTEN..  YES TO 5550                LIN7 427
      GO TO (5560,5550),MPNT                                            LIN7 428
 5550 WRITE(ISOUT,12)XP(J),YP(J),ZP(J),TP(J),TSM,NTI,NG,NTO,NW,NLOST,   LIN7 429
     1IR                                                                LIN7 430
C                                                                       LIN7 431
C      TEST FOR PARTICLE IMPACT ON TOPOGRAPHY                           LIN7 432
 5560 IF(ZP(J)-ITOPO)187,187,189                                        LIN7 433
C                                                                       LIN7 434
C 189 PARTICLE IS NOT G-OUNDED.  ADJUST INDICES JW AND JWAD AND THEN    LIN7 435
C      RECYCLE.                                                         LIN7 436
 189  GO TO (250,250,252,159,195),IR                                    LIN7 437
 159  NTI=NTI+1                                                         LIN7 438
      TP(J)=ENDTIM                                                      LIN7 439
      GO TO 160                                                         LIN7 440
 250  JW=-JW                                                            LIN7 441
      GO TO 1950                                                        LIN7 442
 252  IF(VZ(JWAD))258,258,259                                           LIN7 443
 258  JW=1-JW                                                           LIN7 444
      GO TO 1961                                                        LIN7 445
 259  JW=-(JW+1)                                                        LIN7 446
 270  GO TO 1961                                                        LIN7 447
 187  GO TO IT,(188,1871)                                               LIN7 448
 1871 X=XP(J)                                                           LIN7 449
      Y=YP(J)                                                           LIN7 450
      CALL HEIGHT(X,Y,H)                                                LIN7 451
      IF(H+20000.0)1872,1872,1874                                       LIN7 452
 1874 IF(H+10000.0)1875,1875,1876                                       LIN7 453
C                                                                       LIN7 454
C 1872 H=-20000.0     PARTICLE BEYOND SPECIFIED TOPO                    LIN7 455
 1872 FMAS(J)=-FMAS(J)                                                  LIN7 456
      TP(J)=TLIMIT                                                      LIN7 457
      NLOST=NLOST+1                                                     LIN7 458
      GO TO 160                                                         LIN7 459
C                                                                       LIN7 460
C 1875  H=-10000.0     PARTICLE BEYOND IN-CORE TOPO                     LIN7 461
 1875 TP(J)=-TP(J)                                                      LIN7 462
      NTO=NTO+1                                                         LIN7 463
      IF(JTOP1)160,1877,160                                             LIN7 464
 1877 JTOP1=-1                                                          LIN7 465
      GO TO 160                                                         LIN7 466
 1876 IF(H-ZP(J))189,188,188
C
C 188  TAKES CARE OF GROUNDED PARTICLES
 188  FMAS(J)=-FMAS(J)
      TP(J)=-TP(J)
      NG=NG+1
 160  CONTINUE
C
C *********************************************************************
C
C     END OF MAIN TRANSPORT LOOP
C
C *********************************************************************
C
      IF(JDONE-1)1000,100,1000
C
C     ARE ANY PARTICLES ON THE OFF THE TOPO TAPE
 100  IF(JTOP1)105,104,105
C     JTOP1 GR    ZERO INDICATES SOME PARTICLES ARE ON OFF TOPO TAPE
C     A NEGATIVE JTOP1 INDICATES PARTICLES IN OFF TOPO BUFFER BUT NOT
C     ON THE OFF TOPO TAPE
C
C     ARE ANY PARTICLES ON THE OUT OF WIND FIELD TAPE
 104  IF(JWIND1)130,200,130
C 200  IS PARTICLES ALOFT TIME BOUNDARY TAPE IN USE $$
 200  IF(JTIME1)203,203,201
 203  IF(NTI)2021,2031,2021
 2021 JTIME1=-1
      JDONE = 1
      GO TO 202
 2031 ENDTIM=TLIMIT
      GO TO 202
 201  WRITE(IPAROT)NUL
      REWIND IPAROT
      REWIND IPARIN
      ITEMP=IPARIN
      IPARIN =IPAROT
      IPAROT=ITEMP
      JTIME1=0
      IF(NTI)2022,202,2022
 2022 JTIME1=-1
 202  IEXEC=2
      RETURN
C
C     A NEGATIVE JWIND1 INDICATES SOME PARTICLES ARE IN THE OUT OF THE
C     WIND FIELD BUFFER BUT NOT ON TAPE
C     JWIND1 GREATER THAN ZERO INDICATES PARTICLES ARE ON THE OUT OF
C     THE WIND FIELD TAPE
C
C
C  105 GET THE REQUIRED TOPO DATA FROM TAPE
C     105 TO 107 SCANS BUFFER PARTICLE COUNTERS TO DETERMINE NEXT NEEDED
C     TOPO DATA BLOCKS AND CHOOSES THE NEAREST ONE FOR READING.
C
C     NBLCK  IS SET BY THE INITIALIZING PROGRAM WHICH READS THE TOPO
C     TAPES IDENTIFICATION RECORDS
C     NINTAR(J) IS SET BY THE TRANSPORT LOOP WHEN PARTICLES LEAVE TOPO
C     AND RESET WHEN OFF-TOPO BUFFER IS EMPTIED.
```

```
C
 105  JTEST=1000
      DO 107 J=1,NBLCK
      JTEST1=NINTAR(J)
      IF(JTEST1)107,107,108
 108  JTEST2=JFTOPO-J+1
      IF(JTEST2)109,110,111
 110  IRROR=-110
C
C     SEEKS THE FILE IN CORE. SHOULD NEVER HAPPEN. GO TO A STOP EXIT.
      GO TO 300
 111  IF(JTEST2-JTEST)112,107,107
 112  JTEST=JTEST2
      GO TO 140
 109  IF(JTEST+JTEST2)107,107,113
 113  JTEST=-JTEST2
 140  JF=J
 107  CONTINUE
C
C     AT THIS POINT JF HAS THE NUMBER OF THE DESIRED FILE
C     NOW MOVE TAPE TO SELECTED FILE
      IF(JF-JFTOPO)1072,1071,1071
C
C 1071 PREPARE TO MOVE FORWARD ON IHTOPO.  COMPUTE NUMBER OF BLOCKS TO
C     READ IN
 1071 JR=JF-JFTOPO+1
      GO TO 1074
C
C 1072 DESIRED FILE IS BEHIND READ HEAD.  BACK UP TO GET IT.
 1072 REWIND IHTOPO
C
C     NOW SKIP OVER INITIAL RECORDS
      READ (IHTOPO)TST
      READ (IHTOPO)TST,TST,TST,TST,TST
      READ (IHTOPO)TOPOLM
      READ (IHTOPO)ITOPLM
      JR=JF
C
C 1074 NOW READ UP THROUGH THE DESIRED BLOCK
 1074 DO 1073 J=1,JR
 1073 CALL RDTOPO(J)
C
C 116 RESET ALL OFF-TOPO PARTICLES
 116  DO 118 J=1,NALOFT
      IF(FMAS(J))117,118,118
 117  IF(TP(J))119,118,118
 119  IF(TP(J)-TLIMIT)120,118,120
 120  FMAS(J)=-FMAS(J)
      TP(J)=-TP(J)
 118  CONTINUE
      IF=NALOFT
      IF(JTOP1)1151,115,115
 1151 JTOP1=0
      JTIME1=-1
      GO TO 1001
C
C 115 REWIND OFF TOPO AND PARTICLES ALOFT TAPES AND SWAP NAMES
 115  WRITE(IOTOPO)NUL
```

```
      REWIND IOTOPO                                                     LIN7 583
      REWIND IPARIN                                                     LIN7 584
      ITEMP=IOTOPO                                                      LIN7 585
      IOTOPO=IPARIN                                                     LIN7 586
      IPARIN=ITEMP                                                      LIN7 587
      JTOP1=0                                                           LIN7 588
      GO TO 1001                                                        LIN7 589
C                                                                       LIN7 590
C 130  GET THE REQUIRED WIND FIELD DATA FROM TAPE                       LIN7 591
 130  GO TO 124                                                         LIN7 592
C    INSERT CODE HERE                                                   LIN7 593
C                                                                       LIN7 594
C     RESET ALL IN-CORE OUT-OF-WIND-FIELD PARTICLE KEYS                 LIN7 595
 124  DO 122 J=1,NALOFT                                                 LIN7 596
      IF(FMAS(J)) 1241,122,122                                          LIN7 597
 1241 IF(TP(J))122,122,1242                                             LIN7 598
 1242 IF(TP(J)-TLIMIT)1243,122,1243                                     LIN7 599
 1243 FMAS(J)=-FMAS(J)                                                  LIN7 600
 122  CONTINUE                                                          LIN7 601
      IF=NALOFT                                                         LIN7 602
      IF(JWIND1)123,125,125                                             LIN7 603
 123  JWIND1=0                                                          LIN7 604
      JTIME1=-1                                                         LIN7 605
      GO TO 1001                                                        LIN7 606
C 125 REWIND OUT OF WIND AND PARTICLES ALOFT TAPES AND SWAP NAMES       LIN7 607
 125  WRITE (IOWIND,10)NOL                                              LIN7 608
      JWIND1=0                                                          LIN7 609
      REWIND IOWIND                                                     LIN7 610
      REWIND IPARIN                                                     LIN7 611
      ITEMP=IOWIND                                                      LIN7 612
      IOWIND=IPARIN                                                     LIN7 613
      IPARIN=ITEMP                                                      LIN7 614
      GO TO 1001                                                        LIN7 615
C                                                                       LIN7 616
      END                                                               LIN7 617
                                                                              618*

                                                                              618 *
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$IBFTC GETWN    LIST,DECK,M94/2
      SUBROUTINE GETWND(XX,YY,ZZ,JWAD,JW)
C     28 NOVEMBER 1966
C     T.W. SCHWENKE     TECHNICAL OPERATIONS RESEARCH
C
C ***********************************************************************
C
C     THIS SUBROUTINE RETRIEVES THE MACRO WIND FIELD VECTOR WHICH
C     APPLIES AT THE POINT WHOSE COORDINATES ARE IN THE ARGUMENT WORDS
C     XX,YY, ANDZZ AT ENTRANCE.  THE X,Y, AND Z WIND VECTOR COMPONENTS
C     ARE IN THE COMMON VARIABLES VX(JWAD),VY(JWAD), AND VZ(JWAD) WHEN
C     THE SUBROUTINE RETURNS.  IF AN ENTRANCE IS MADE WITH ARGUMENT JW
C     SET NEGATIVE, JW IS SET POSITIVE AND ITS-VALUE IS USED RATHER THAN
C     RECOMPUTED.  UPON EXIT JWAD IS SET NEGATIVE IN THE EVENT THAT THE
C     MACRO WIND FIELD PERTAINING TO THE DESIRED POINT IS NOT AVAILABLE
C     IN CORE.
C
C **************************  GLOSSARY  *********************************
C
C     JW           INDEX OF THE WIND ARRAY STRATA IN THE MACRO WIND FIELD.
C                  THIS INDEX INCREASES FROM BOTTOM TO TOP OF THE FIELD.
C                  IF NEGATIVE AT ENTRANCE, IT IS SET POSITIVE AND USED BY
C                  GETWND.  IF ZERO OR POSITIVE AT ENTRANCE, IT IS RE-
C                  COMPUTED BY GETWND.
C     JWAD         AN INDEX FOR THE STORAGE ARRAYS (ONE DIMENSIONAL) FOR
C                  MACRO WIND FIELD VECTORS.  JWAD IS SET NEGATIVE BY
C                  GETWND IF THE NEEDED MACRO WIND FIELD VECTORS ARE NOT
C                  IN CORE.
C     JT           INDEX OF WIND LAYER USED IN A SEARCH FOR THE LAYER CON-
C                  TAINING THE J-TH PARTICLE.  TOP INDEX
C     JTOPJ        INDEX OF THE TOP LAYER IN THE MACRO WIND FIELD DESCRIP-
C                  TION
C     JTST         TEMPORARY STORAGE
C     ZZ           Z COORDINATE OF THE POINT FOR WHICH A MACRO WIND FIELD
C                  VECTOR IS SOUGHT
C     XX           X COORDINATE.   SEE ZZ
C     YY           Y COORDINATE.   SEE ZZ
C     IRROR        NUMBER OF THE STATEMENT NEAR THE POINT WHERE AN ERROR
C                  WAS DISCOVERED
C     WLLX(JW)     LOWER LIMIT FOR X COORDINATES IN THE MACRO WIND FIELD
C     WLLY(JW)     LOWER LIMIT FOR Y COORDINATES IN THE MACRO WIND FIELD
C     WURX(JW)     UPPER LIMIT FOR X COORDINATES IN THE MACRO WIND FIELD
C     WURY(JW)     UPPER LIMIT FOR Y COORDINATES IN THE MACRO WIND FIELD
C     IIW          X DIRECTION WIND FIELD RETRIEVAL INDEX
C     JJW          Y DIRECTION WIND FIELD RETRIEVAL INDEX
C     WGRINT(JW)   GRID INTERVAL FOR THE WIND FIELD IN JW-TH STRATUM IN
C                  METERS
C     IL(JW)       THE NUMBER OF GRID DIVISIONS IN THE X DIRECTION OF THE
C                  WIND FIELD IN STRATUM JW
C     IBADD(JW)    BASE ADDRESS FOR STORING DATA FROM THE JW-TH STRATUM OF
C                  THE WIND FIELD.  THIS IS AN INDEX IN THE 1-D WIND ARRAY
C
C ***********************************************************************
C
      COMMON /SET1/
     1           DIAM    , DETID   , IRISE   , IEXEC   , ISIN    , ISOUT     ,
     2           SD      , SPAR    , SSAM    , TME     , TMP1    , TMP2      ,
     3           T2M     , J       , VPR     , W       , X       , Z         ,
     4           WHY     , RMIN    , IDISTR  , SPAR1   , SPAR2   , SPAR3     ,
     5           SPAR4   , SPAR5   , SPAR6   , SPAR7   , SPAR8   , SPAR9
      DIMENSION  DETID(12),WHY(40)
```

```
C
C ******************************************************************************
C
      COMMON /SET2/
     1        S       , SUBSID , GRINT  , BXLL   , BXLU   , BYLL
     2,       BYLU    , TXLL   , TXLU   , TYLL   , TYLU   , XGZ
     3,       YGZ     , NBLOCK , HTOPO  , TTOPO  , ILIM   , JLIM
     4,       KLIM    , II     , JJ     , KK     , XP     , YP
     5,       ZP      , FMAS   , TP     , PS     , VX     , VY
     6,       VZ      , IL     , JL     , IBADD  , WORINT , NOTPAR
     7,       WLLX    , WLLY   , WORX   , WORY   , BOTHIT , IPARIN
     8,       IOTOPO  , IOWIND , IHTOPO , IPOUT  , IPAROT , JTOPI
     9,       JWINDI  , IRROR  , TLIMIT , ENDTIM , IC     , ISTPRO
     1,       JTOPJ   , NLOST  , NG     , NTO    , NTI    , NN
     2,       NALOFT  , JTIMEI , NOMAX  , NFREE  , N      , NCL
     3,       CRMAXY  , CROHT  , NCRTYP , BZ     , CRMINX , CRMINY
     4,       JJ      , SN     , CS     , NLOCIR , JTLOC  , ATEMP
     5,       RHO     , NA     , TGZ    , DTMAC  , PROG   , CRMAXX
     6,       NOPART
      DIMENSION IOPOLN(4,4)   ,NINTAR(4)      ,ITOPLM(3,4)
      DIMENSION S(10,10)      ,SUBSID(400)    ,IC(18)
      DIMENSION XP(200)       ,YP(200)        ,ZP(200)        ,FMAS(200)
      DIMENSION TP(200)       ,PS(200)        ,ATEMP(200)     ,RHO(200)
      DIMENSION VX(1500)      ,VY(1500)       ,VZ(1500)       ,IL(70)
      DIMENSION JL(70)        ,IBADD(70)      ,WORX(70)
      DIMENSION WORINT(70)                    ,WLLX(70)       ,WLLY(70)
      DIMENSION WORY(70)      ,BOTHIT(70)     ,SN(6)          ,CS(6)
      DIMENSION CRMINX(6)     ,CRMAXX(6)      ,CRMINY(6)      ,CRMAXY(6)
      DIMENSION CROHT(6)      ,NCRTYP(6)      ,JJ(6)
C
C ******************************************************************************
C
      DATA PROG/6HGETWND/
C
C ******************************************************************************
C ******************************************************************************
C
C     TEST FOR SPECIAL ENTRANCE FROM MAIN TRANSPORT LOOP WITH JW SET -.
      IF(JW)100,102,102
C 100 SPECIAL ENTRANCE.   MAGNITUDE OF JW IS STILL VALID.
 100  JW=-JW
      GO TO 270
C     REGULAR ENTRANCE               COMPUTE JW
C     FIND INDEX OF WIND FIELD LAYER THAT CONTAINS THE POINT XX,YY,ZZ
C     AND STORE IT IN JW.  USE A TWO-BOUNDED BINARY SEARCH.
 102  JT=JTOPJ+1
      JW=1
C
C 153  COMPUTE TRIAL INDEX NUMBER
 153  JTST=(JT+JW)/2
C     HAVE TRIAL TOP AND BOTTOM INDICES CONVERGED TO INDICATE THE
C     DESIRED LAYER.   NO TO 154
      IF(JT-JW-1)155,270,154
C
C 154  IS PARTICLE ABOVE THE BOTTOM OF THE TRIAL LAYER.    NO TO 152
 154  IF(ZZ-BOTHIT(JTST))152,150,150
C 150  PARTICLE IS IN OR ABOVE SLICE JTST.
  150 JW=JTST
```

```
      GO TO 153                                                          GETW 119
C 152  PARTICLE IS BELOW SLICE JTST                                      GETW 120
  152 JT=JTST                                                            GETW 121
      GO TO 153                                                          GETW 122
 155  IRROR=-155                                                         GETW 123
 7734 CALL ERROR(PROGRM,IRROR,IOOUT)                                     GETW 124
C                                                                        GETW 125
C                                                                        GETW 126
C 270  IS THE PARTICLE WITHIN THE SPECIFIED WIND FIELD.     NO TO 271    GETW 127
 270  IF(XX-WLLX(JW))271,272,272                                         GETW 128
C 271 MARK PARTICLE BEYOND SPECIFIED WIND FIELD                          GETW 129
 271  JWAD=-1                                                            GETW 130
      GO TO 160                                                          GETW 131
 272  IF(XX-WURX(JW))273,273,271                                         GETW 132
 273  IF(YY-WLLY(JW))271,275,275                                         GETW 133
 275  IF(YY-WURY(JW))274,274,271                                         GETW 134
C                                                                        GETW 135
C 274 IS SPECIFIED WIND FIELD IN CORE      ALWAYS YES IN THIS PROGRAM    GETW 136
 274  CONTINUE                                                           GETW 137
C 276       NOW COMPUTE JWAD - THE INDEX OF THE APPLICABLE WIND CELL     GETW 138
 276  IIW=  (XX-WLLX(JW))/WSXINT(JW)                                     GETW 139
      JJW=  (YY-WLLY(JW))/WSYINT(JW)                                     GETW 140
      JWAD=IBADD(JW)+(JJW   )*IC(JW)+IIW                                 GETW 141
 160  RETURN                                                             GETW 142
      END                                                                GETW 143
                                                                              144*

                                                                              144 *
```

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$IBFTC LOTRA    LIST,DECK,M94/2
      SUBROUTINE LOTRAN(J,K)
C     11 OCT 66
C     T.W.SCHWENKE         TECHNICAL OPERATIONS RESEARCH
C
C ****************************************************
C
C     THIS IS THE EXECUTIVE ROUTINE FOR TRANSPORTING PARTICLES WITHIN
C     ALL LOCAL WIND SYSTEMS.
C     IF THE J-TH PARTICLE IS ABOVE THE TOP OF THE LOCAL CIRCULATION
C     CELL, LOTRAN TRANSPORTS IT USING WIND VECTORS RETRIEVED FROM THE
C     MACRO WIND FIELD ARRAYS.  FOR PARTICLES LOCATED IN THE LOCAL
C     CIRCULATION CELL IT CALLS THE APPROPRIATE LOCAL CIRCULATION CODE
C     TO OBTAIN AN ESTIMATE OF THE WIND VECTOR AT PARTICLE POSITION.
C     IN EITHER CASE THE PARTICLE IS TRANSPORTED FOR ONE TIME STEP OF
C     DURATION DT SECONDS.   THIS PROCEDURE IS REPEATED UNTIL THE
C     PARTICLE LEAVES THE LOCAL CELL OR LANDS ON THE PREVIOUSLY
C     DESCRIBED TOPOGRAPHY OR UNTIL THE TIME (ENDTIM) FOR UPDATING THE
C     ENTIRE WIND FIELD IS REACHED.  PARTICLES MAY FALL INTO THE LOCAL
C     CELL FROM ABOVE DURING TRANSPORT.
C
C *******************        GLOSSARY     ****************************
C
C     AX             A COMPONENT OF A WIND VECTOR RETRIEVED FROM A LOCAL
C                    WIND FIELD DESCRIPTION.  METERS/SEC.
C     AY             Y COMPONENT  -  SEE AX
C     AZ             Z COMPONENT  -  SEE AX
C     CRMINX(K)      COORDINATE OF THE WESTERN BOUNDING PLANE FOR THE K-TH
C                    LOCAL CIRCULATION SYSTEM CELL
C     CRMINY(K)      SEE CRMINX(K) - SOUTHERN BOUNDARY
C     CRMAXY(K)      SEE CRMINX(K) - NORTHERN BOUNDARY
C     CRMAXX(K)      SEE CRMINX(K) - EASTERN BOUNDARY
C     CRTOP(K)       ALTITUDE (METERS ABOVE MSL) OF THE TOP BOUNDARY OF THE
C                    K-TH LOCAL CIRCULATION CELL
C     DTLOC          TIME STEP DURATION (SECONDS) FOR TRANSPORT WITHIN [illegible]
C                    LOCAL CIRCULATION CELLS
C     ENDTIM         TIME FOR THE NEXT UPDATING OF THE WIND FIELD. SECONDS
C     FV             SETTLING RATE (ABSOLUTE VALUE IN METERS/SEC.) OF THE
C                    J-TH PARTICLE AS COMPUTED BY SUBROUTINE FALRAT
C     IERROR         STATEMENT NEAR THE POINT WHERE AN ERROR WAS DISCOVERED
C     J              INDEX FOR PARTICLE DESCRIPTIONS
C     JW             INDEX OF THE WIND ARRAY STRATA IN THE MACRO WIND FIELD.
C                    THIS INDEX INCREASES FROM BOTTOM TO TOP OF THE FIELD.
C                    IF NEGATIVE AT ENTRANCE, IT IS SET POSITIVE AND USED BY
C                    GETWND.  IF ZERO OR POSITIVE AT ENTRANCE, IT IS RE-
C                    COMPUTED BY GETWND.
C     JWAD           AN INDEX FOR THE STORAGE ARRAYS (ONE DIMENSIONAL) FOR
C                    MACRO WIND FIELD VECTORS.  JWAD IS SET NEGATIVE BY
C                    GETWND IF THE NEEDED MACRO WIND FIELD VECTORS ARE NOT
C                    IN CORE.
C     JWT            TEMPORARY INDEX OF THE BOUNDING PLANE
C     K              ARGUMENT OF LOTRAN THAT COMMUNICATES THE INDEX OF THE
C                    LOCAL SYSTEM CELL IN OR ABOVE WHICH THE J-TH PARTICLE
C                    IS LOCATED WHEN LOTRAN IS CALLED
C     NC             A BRANCH POINT VARIABLE FOR USE WITH AN ASSIGNED GO TO
C                    NC THAT EFFICIENTLY TRANSFERS TO THE APPROPRIATE LOCAL
C                    CIRCULATION SYSTEM PROGRAM DURING EXECUTION OF THE
C                    LOCAL TRANSPORT LOOP
C     NCIR           TEMPORARY NON-SUBSCRIPTED STORAGE FOR LOCAL CIRCULATION
C                    SYSTEM TYPE NUMBER
C     NCRTYP(K)      TYPE DESIGNATION FOR THE K-TH LOCAL CIRCULATION SYSTEM
```

```
C              SEE THE EXPLANATION OF TYPE NUMBERS BELOW.                 LOTR  61
C                   1                MTWND1                               LOTR  62
C                   2                RGWND1                               LOTR  63
C                   3                CBREZ1                               LOTR  64
C                   4              NOT ASSIGNED                           LOTR  65
C                   5              NOT ASSIGNED                           LOTR  66
C      TCELLT    SEE TXX.   FOR THE PLANE DEFINING LOCAL CELL TOP         LOTR  67
C      TLAYER    SEE TXX.   FOR THE HORIZONTAL PLANES BOUNDING THE MACROLOTR  68
C                WIND FIELD LAYER THAT THE PARTICLE IS IN                 LOTR  69
C      TP(J)     TIME COORDINATE FOR THE J-TH PARTICLE                    LOTR  70
C                SINCE DETONATION                                         LOTR  71
C      TXX       TIME OF FLIGHT TO NEXT (IN TIME) INTERCEPT BETWEEN       LOTR  72
C                PARTICLE TRAJECTORY AND AN X=CONSTANT PLANE BOUNDING     LOTR  73
C                THE LOCAL WIND CELL                                      LOTR  74
C      TYY       SEE TXX.   FOR A Y-BOUNDARY PLANE                        LOTR  75
C      VPZ       VERTICAL PARTICLE VELOCITY, M/SEC.                       LOTR  76
C      VX( )     X COMPONENT ARRAY OF THE MACRO WIND FIELD DESCRIPTION    LOTR  77
C      VY( )     Y COMPONENT - SEE VX( )                                  LOTR  78
C      VZ( )     Z COMPONENT - SEE VX( )                                  LOTR  79
C      XP(J)     X COORDINATE OF THE J-TH PARTICLE.  A COMMON ARRAY       LOTR  80
C      XX        X COORDINATE OF THE POINT FOR WHICH GETWND IS TO GET     LOTR  81
C                THE APPLICABLE MACRO WIND VECTOR                         LOTR  82
C      YP(J)     Y COORDINATE OF THE J-TH PARTICLE.  A COMMON ARRAY       LOTR  83
C      YY        Y COORDINATE - SEE XX                                    LOTR  84
C      ZP(J)     Z COORDINATE OF THE J-TH PARTICLE.  A COMMON ARRAY       LOTR  85
C                ALTITUDE OF J-TH PARTICLE IN METERS ABOVE MSL            LOTR  86
C      ZZ        Z COORDINATE - SEE XX                                    LOTR  87
C                                                                         LOTR  88
C*************************************************************************LOTR  89
C                                                                         LOTR  90
      COMMON /SET1/                                                       LOTR  91
     1          DIAM   , DETID  , TRICE  , CLASS  , IDIR   , ISOCT    ,   LOTR  92
     2          GD     , SPAR   , GSAM   , THE    , TPPZ   , TMPZ     ,   LOTR  93
     3          TZR    , U      , VPR    , W      , X      , Z        ,   LOTR  94
     4          AMY    , RMIN   , IDISTR , SPAR1  , SPAR2  , SPAR3    ,   LOTR  95
     5          SPAR4  , SPAR5  , SPAR6  , SPAR7  , SPAR8  , SPAR9        LOTR  96
      DIMENSION  DETID(12),AMY(40)                                        LOTR  97
C                                                                         LOTR  98
C*************************************************************************LOTR  99
C                                                                         LOTR 100
      COMMON /SET2/                                                       LOTR 101
     1          G      , SUBSID , GRINT  , DXLL   , DXLU   , DYLL         LOTR 102
     2,         DYLU   , TXLL   , TXLU   , TYLL   , TYLU   , XGZ          LOTR 103
     3,         YGZ    , NMAXN  , HTOPO  , TTOPO  , TLIM   , DLIM         LOTR 104
     4,         REIT   , II     , JJ     , KK     , XP     , YP           LOTR 105
     5,         ZP     , PMAS   , TP     , PD     , VX     , VY           LOTR 106
     6,         VZ     , IL     , JL     , IDADD  , WORINT , NSTRAT       LOTR 107
     7,         XCCX   , XCCY   , XORX   , XORY   , SUTHIT , IPARIN       LOTR 108
     8,         IOTOPO , IGWIND , IHTOPO , IPOUT  , IPAROT , DTCPI        LOTR 109
     9,         GWINDI , IXNOX  , TLIMIT , ENDTIM , IC     , ISTPAS       LOTR 110
     1,         DTOPO  , RESULT , NG     , NTC    , NTI    , NW           LOTR 111
     2,         NALOFT , DTIMEI , NBMAX  , NPREL  , N      , NCL          LOTR 112
     3,         CRMAXY , CRUMT  , VCRTFP , DZ     , CRMINX , CRMINY       LOTR 113
     4,         CD     , SN     , CS     , RLOCIR , DTLOC  , ATEMP        LOTR 114
     5,         RHO    , NA     , TSZ    , DTMAC  , PROB   , CRMAXX       LOTR 115
     6,         ROPART                                                    LOTR 116
      DIMENSION TOPOLM(4,4)    ,WINTAR(4)       ,ITOPLM(3,4)              LOTR 117
      DIMENSION G(10,10)       ,SUBSID(400)     ,IC(18)                   LOTR 118
      DIMENSION XP(200)         ,YP(200)        ,ZP(200)        ,FMAS(200)
      DIMENSION TP(200)         ,PS(200)        ,ATEMP(200)     ,RHO(200)
      DIMENSION VX(1500)        ,VY(1500)       ,VZ(1500)       ,IL(70)
      DIMENSION JL(70)          ,IBADD(70)      ,WORX(70)
      DIMENSION WGRINT(70)                      ,WLLX(70)       ,WLLY(70)
      DIMENSION WORY(70)        ,BOTHIT(70)     ,SN(6)          ,CS(6)
      DIMENSION CRMINX(6)       ,CRMAXX(6)      ,CRMINY(6)      ,CRMAXY(6)
      DIMENSION CROHT(6)        ,NCRTYP(6)      ,UU(6)
C
C ***********************************************************************
C
      DATA PROGRM/6HLOTRAN/
C
C ***********************************************************************
C ***********************************************************************
C
C     PUT LOCAL CIRCULATION TYPE NUMBER IN TEMPORARY STORAGE
      NCIR=NCRTYP(K)
C     MAKE AN ASSIGNMENT TO ALLOW AN EFFICIENT
C     BRANCH TO THE APPROPRIATE LOCAL CIRCULATION TRANSPORT CODE
C     IN THE ACTUAL LOCAL TRANSPORT LOOP
      GO TO (101,102,103,104,105),NCIR
 101  ASSIGN 121 TO NC
      GO TO 120
 102  ASSIGN 122 TO NC
      GO TO 120
 103  ASSIGN 123 TO NC
      GO TO 120
 104  ASSIGN 124 TO NC
      GO TO 120
 105  ASSIGN 125 TO NC
C
C 120 BEGIN THE LOCAL TRANSPORT LOOP.
C     FIRST DETERMINE IF THE PARTICLE IS BELOW THE LEVEL OF THE TOP
C     OF THE K-TH LOCAL CIRCULATION SYSTEM CELL.  IF IT IS NOT, CALL
C     GETWIND TO GET THE MACRO WIND VECTOR AT PARTICLE POSITION AND THEN
C     MOVE THE PARTICLE BY TRANSFERING TO 130. IF PARTICLE IS WITHIN THE
C     LOCAL CELL, A BRANCH MUST BE MADE TO THE APPROPRIATE SUBROUTINE.
 120  ZZ=ZP(J)
      PSIZE=PS(J)
      CALL FALRAT(ZZ,PSIZE,FV,ATEMP,RHO,PROG,ISOUT)
      IF(ZP(J)-CROHT(K))1202,1202,1201
C 1201 PARTICLE IS ABOVE LOCAL CELL
 1201 XX = XP(J)
      YY = YP(J)
      ZZ = ZP(J)
      CALL GETWND(XX,YY,ZZ,JWAD,JW)
C     WAS THE MACRO WIND FIELD SPECIFICATION AVAILABLE FOR THE PARTICLE
C     POSITION.  NO TO 1203
      IF(JWAD)1203,1203,1204
C 1203 MACRO WIND FOR THIS PARTICLE IS NOT AVAILABLE.
 1203 IRROR = 1203
      GO TO 7734
C
C 1204 COMPUTE VERTICAL COMPONENT OF PARTICLE VELOCITY
 1204 VPZ=VZ(JWAD)-FV
C
C     COMPUTE TIMES OF FLIGHT TO ALL BOUNDARY INTERCEPTS THAT ARE IN THE
```

```
C      FUTURE.  FIRST COMPUTE TIME TO COMING X BOUNDARY OF LOCAL CELL
       IF(VX(JWAD))1205,1206,1206
 1205  TXX=(XP(J)-CRMINX(K))/VX(JWAD)
       GO TO 1207
 1206  TXX=(CRMAXX(K)-XP(J))/VX(JWAD)
C
C 1207 COMPUTE TIME  TO COMING Y BOUNDARY INTERCEPT
 1207  IF(VY(JWAD))1208,1209,1209
 1208  TYY=(YP(J)-CRMINY(K))/VY(JWAD)
       GO TO 1210
 1209  TYY=(CRMAXY(K)-YP(J))/VY(JWAD)
C
C 1210 COMPUTE TIMES TO COMING Z BOUNDARY (HORIZONTAL) OF MACRO WIND
C      FIELD AND TO THE TOP OF THE LOCAL WIND CELL
 1210  IF(VPZ)1211,1212,1212
 1211  TCELLT=(CROHT(K)-ZP(J))/VPZ
       JWT=JW
       GO TO 1213
 1212  TCELLT=1.0E+08
       JWT=JW+1
 1213  TLAYER=(BOTHIT(JWT)-ZP(J))/VPZ
C
C       COMPUTE TIME UNTIL TIME FOR UPDATING THE WIND FIELD
       TTIM=ENDTIM-TP(J)
C
C      NOW SELECT THE TIME  UNTIL THE FIRST VALID BOUNDARY INTERCEPT
C      ADD A SMALL INCREMENT TO PUSH THE PARTICLE PAST THE BOUNDARY OF
C      THE LOCAL CELL.
       TTRANS=AMIN1(TXX,TYY,TCELLT,TLAYER,TTIM) +.01
C
C      NOW TRANSPORT THE PARTICLE FOR THAT PERIOD OF TIME
       XP(J)=XP(J)+TTRANS*VX(JWAD)
       YP(J)=YP(J)+TTRANS*VY(JWAD)
       ZP(J)=ZP(J)+TTRANS*VPZ
       TP(J)=TP(J)+TTRANS
       GO TO 131
C
C 1202 PARTICLE IS WITHIN LOCAL CELL.  BRANCH TO CALL APPROPRIATE WIND
C      PROGRAM
C      BRANCH TO CALL A LOCAL WIND PROGRAM TO TEST PARTICLE FOR IMPACT ONTO
C      TOPOGRAPHY.  IF IMPACTED,IT ASSIGNS A LARGE DOWNWARD WIND COM-
C      PONENT.  IF NOT IMPACTED, IT COMPUTES CORRECT WIND COMPONENTS AT
C      THE PARTICLE POSITION
 1202  GO TO NC,(121,122,123,124,125)
 121   CALL MTWND1(J,K,AX,AY,AZ)
       GO TO 130
 122   CALL RGWND1(J,K,AX,AY,AZ)
       GO TO 130
 123   CALL CBREZ1(J,K,AX,AY,AZ)
       GO TO 130
C *********  CODE INSERTION  POINTS  ************************************
 124   CONTINUE
 125   CONTINUE
C *********  CODE INSERTION  POINTS  ************************************
 126   IRROR=-126
 7734  CALL ERROR(PROGRM,IRROR,ISOUT)
C
C 130  TRANSPORT THE PARTICLE FOR ONE TIME INCREMENT  (DTLOC).
```

```
 130  ZP(J)=ZP(J)+ DTLOC*(AZ-FV)                                       LOTR 235
      XP(J)=XP(J)+ DTLOC*AX                                           LOTR 236
      YP(J)=YP(J)+ DTLOC*AY                                           LOTR 237
      TP(J)=TP(J)+ DTLOC                                              LOTR 238
C                                                                     LOTR 239
C 131 TEST FOR BOUNDARY CROSSINGS                                     LOTR 240
C     IS PARTICLE AT OR BEYOND THE LOCAL CIRCULATION BOUNDARIES       LOTR 241
C     YES TO 132                                                      LOTR 242
 131  IF(XP(J)-CRMINX(K))132,132,133                                  LOTR 243
 133  IF(CRMAXX(K)-XP(J))132,132,134                                  LOTR 244
 134  IF(YP(J)-CRMINY(K))132,132,135                                  LOTR 245
 135  IF(CRMAXY(K)-YP(J))132,132,137                                  LOTR 246
C 137 TEST TO REMOVE IMPACTED PARTICLES                               LOTR 247
C     WAS THE PARTICLE BELOW THE ANALYTICAL TOPOGRAPHY WHEN THE LOCAL LOTR 248
C     WIND WAS COMPUTED.   YES TO 132                                 LOTR 249
 137  IF(AZ-1.0E+06)132,132,138                                       LOTR 250
C                                                                     LOTR 251
C 138 PARTICLE IS STILL WITHIN KTH LOCAL SYSTEM. NOW CHECK TIME BOUNDARYLOTR 252
C     HAS THE PARTICLE BEEN TRANSPORTED UP TO OR BEYOND THE TIME FOR  LOTR 253
C     UPDATING THE WIND FIELD                                         LOTR 254
 138  IF(TP(J)-ENDTIM)120,132,132                                     LOTR 255
C                                                                     LOTR 256
C 132 PARTICLE CANNOT BE MOVED FURTHER BY LOCAL SYSTEM TRANSPORT CODE LOTR 257
C                                                                     LOTR 258
  132 RETURN                                                          LOTR 259
      END                                                             LOTR 260
                                                                          261*

                                                                          261 *
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$IBFTC MTWN1    LIST,DECK,M94/2
      SUBROUTINE MTWND1(J,K,AX,AY,AZ)
C     11 OCT 66
C     I. KOHLBERG, T.W.SCHWENKE  TECHNICAL OPERATIONS RESEARCH, INC.
C
C     THIS SUBROUTINE SERVES THE DUAL PURPOSE OF READING MOUNTAIN WIND
C     DATA WHEN THE SIGN OF ARGUMENT J IS MINUS) AND COMPUTING THE
C     MOUNTAIN WIND FOR THE JTH PARTICLE AFTER FIRST CHECKING FOR IMPACT
C     ON THE ANALYTICAL GROUND.  IF IMPACT IS SENSED THE PARTICLE IS
C     ASSIGNED A LARGE DOWNWARD VELOCITY COMPONENT.
C
C ***********************************************************************
C
      COMMON /SET1/
     1          DIAM    , DETID   , IRISE   , IEXEC   , ISTN    , ISOUT     ,
     2          SD      , SPAR    , SSAM    , TME     , TMP1    , TMP2      ,
     3          T2M     , U       , VPR     , W       , X       , Z         ,
     4          WHY     , RMIN    , IDISTR  , SPAR1   , SPAR2   , SPAR3     ,
     5          SPAR4   , SPAR5   , SPAR6   , SPAR7   , SPAR8   , SPAR9
C
C ***********************************************************************
C
      DIMENSION  DETID(12),WHY(40)
      COMMON /SET2/
     1          G       , SUBSID  , GRINT   , BXLL    , BXLO    , BYLL
     2,         BYLO    , TXLL    , TXLO    , TYLL    , TYLO    , XGZ
     3,         YGZ     , NBLCK   , HTOPO   , ITOPO   , ILIM    , JLIM
     4,         KLIM    , II      , JJ      , KK      , XP      , YP
     5,         ZP      , FMAS    , TP      , PS      , VX      , VY
     6,         VZ      , IL      , JL      , IBADD   , WGRINT  , NSTRAT
     7,         WLLX    , WLLY    , WORX    , WORY    , BOTHIT  , IPARIN
     8,         IOTOPO  , IOWIND  , IHTOPO  , IPOUT   , IPAROT  , JTOPI
     9,         OWINDI  , IRROR   , TLIMIT  , ENDTIM  , IC      , IBYPAS
     1,         JTOPO   , NLOST   , NG      , NTO     , NTI     , NW
     2,         NALOFT  , JTIME1  , NBMAX   , NFREE   , N       , NCL
     3,         CRMAXY  , CROHT   , NCRTYP  , SZ      , CRMINX  , CRMINY
     4,         OO      , SN      , CS      , NLOCIR  , DTLOC   , ATEMP
     5,         RHO     , MA      , TGZ     , DTMAC   , FROG    , CRMAXX
     6,         RUPART
      DIMENSION TOPOLM(4,4)   ,NINTAR(4)      ,ITOPLM(3,4)
      DIMENSION S(1 ,10)      ,SUBSID(400)    ,IC(18)
      DIMENSION XP(200)       ,YP(200)        ,ZP(200)        ,FMAS(200)
      DIMENSION TP(200)       ,PS(200)        ,ATEMP(200)     ,RHO(200)
      DIMENSION VX(1500)      ,VY(1500)       ,VZ(1500)       ,IL(70)
      DIMENSION JL(70)        ,IBADD(70)      ,WORX(70)
      DIMENSION WGRINT(70)                    ,WLLX(70)       ,WLLY(70)
      DIMENSION WORY(70)      ,BOTHIT(70)     ,SN(6)          ,CS(6)
      DIMENSION CRMINX(6)     ,CRMAXX(6)      ,CRMINY(6)      ,CRMAXY(6)
      DIMENSION CROHT(6)      ,NCRTYP(6)      ,OO(6)
C ***********************************************************************
C
C     PARAMETERS PECULIAR TO SUBROUTINE MTWND1
C
      DIMENSION XM(12),YM(12),H(12),A(12),A2(12),A2H(12),A3H(12)
C
C*********************MOUNTAIN WIND1 GLOSSARY****************************
C
C     A(J)           HALF-WIDTH OF THE J-TH MOUNTAIN
C     AX             WIND VECTOR EAST
C     AY             WIND VECTOR NORTH
C     AZ             VERTICAL WIND VECTOR
```

```
C     CN(K)          COSINE OF COUNTER CLOCKWISE ANGLE FROM EAST OF
C                    UNPERTURBED WIND
C     CRMAXY(K)      NORTH      BOUNDARY OF THE K-TH LOCAL CELL.
C     CRMINY(K)      SOUTH      BOUNDARY OF THE K-TH LOCAL CELL.
C     CRMAXX(K)      EAST       BOUNDARY OF THE K-TH LOCAL CELL.
C     CRMINX(K)      WEST       BOUNDARY OF THE K-TH LOCAL CELL.
C     CROHT(K)       THE LOCAL CELL TOP HEIGHT  (METERS)
C     DELX
C     DELX           X COORDINATE OF MACROSYSTEM TRANSLATED INTO LOCAL
C                    CELL COORDINATES
C     DELY           Y COORDINATE      SEE DELX
C     DSX            THE X PRIME RESULT OF ROTATION OF (DELX,DELY) INTO
C                    THE K-TH LOCAL COORDINATE SYSTEM.
C     DSY            THE Y PRIME RESULT      SEE DSX
C     DZ             SUM OF TOPO HEIGHT INCREMENTS
C     DZ             MOUNTAIN RATIO OF H(J)/A(J)
C     H(J)           HEIGHT OF THE J-TH MOUNTAIN
CC     NMT           THE NUMBER OF MOUNTAINS REPRESENTED IN THIS MOUNTAIN
C                    WIND SYSTEM
C     SN(K)          SINE OF ANGLE COUNTER-CLOCKWISE FROM EAST OF
C                    UNPERTURBED WIND
C     UU(K)          MAGNITUDE OF UNPERTURBED WIND VECTOR
C     XM(J)          X LOCATION COORDINATE OF THE J-TH MOUNTAIN
C     YM(J)          Y LOCATION COORDINATE OF THE J-TH MOUNTAIN
C     XX             X COORDINATE OF CENTER OF LOCAL CELL
C     YY             Y COORDINATE OF CENTER OF LOCAL CELL
C     ZZ             Z COORDINATE OF CENTER OF LOCAL CELL
C     JW             INDEX OF THE WIND STRATUM CONTAINING THE PARTICLE
C     JWAD           INDEX OF MACRO WIND CELL CONTAINING PARTICLE
C     XP(J)          PARTICLE POSITION COORDINATE
C     YP(J)          PARTICLE POSITION COORDINATE
C     ZP(J)          PARTICLE POSITION COORDINATE
C
C ***************************************************************
C
 1    FORMAT(4F10.3)
 2    FORMAT(//25X24HLOCAL CIRCULATION NUMBERI6/30X15HMOUNTAIN WIND I//1
     15X6HMOUNTAIN4X6HMOUNTAIN4X8HMOUNTAIN4X20HLOCATION COORDINATES/15X6
     2HNUMBER6X6HHEIGHT6X5HWIDTH/X1HX11X1HY)
 3    FORMAT(/12X,I5,6X,4F11.5//)
 4    FORMAT(//25X,36HCOORDINATES OF LOCAL CELL BOUNDARIES/,15X,5HNORTH,
     110X,5HSOUTH,11X,4HEAST,11X,4HWEST,10X,6HHEIGHT//,10X,5F15.5//)
 5    FORMAT(/25X,46HCHARACTERISTICS OF THE UNPERTURBED WIND VECTOR/20X,
     116HUNPERTURBED WIND,4X,17HCOSINE OF ANGULAR,4X,15HSINE OF ANGULAR,
     2/20X,16HVECTOR MAGNITUDE,5X,15HDEV. FROM NORTH,5X,15HDEV. FROM NOR
     3TH//,18X,3F20.5//)
C
C ***************************************************************
C
      DATA PROGRM/6HMTWND1/
C
C ***************************************************************
C ***************************************************************
C
      IF(J)100,101,102
 101  IRROR=-101
7734  CALL ERROR(PROGRM,IRROR,ISOUT)
C
```

```
C 100 THIS IS THE DATA READING ROUTE
 100  J=0
      CRUHT(K)=0.0
 103  J=J+1
      READ (ISIN,1) XM(J),YM(J),H(J),A(J)
      A2(J)=A(J)*A(J)
      A3H(J)=A2(J)*A(J)*H(J)
      IF(J-12)1031,1032,1032
 1032 IRROR=1032
      GO TO 7734
 1031 IF(H(J))1099,104,1099
C1099 COMPUTE THE KTH LOCAL CELL HEIGHT.
 1099 DZ=ABS(3.0*H(J))
      IF (DZ-CRUHT(K))110,110,1100
 1100 CRUHT(K)=DZ
C 110 CHECK TO SEE THAT THE MOUNTAIN JUST READ IS WITHIN THE LIMITS OF
C     THE KTH LOCAL WIND" SYSTEM.
  110 IF(XM(J)-CRMINX(K)) 114,111,111
  111 IF(XM(J)-CRMAXX(K)) 112,112,114
  112 IF (YM(J)-CRMINY(K)) 114,113,113
 113  IF (YM(J)-CRMAXY(K)) 115,115,114
C
C 114 THE MOUNTAIN IS NOT WITHIN THE LIMITS OF THE KTH LOCAL WIND SYSTEM
  114 IRROR= 114
      GO TO 7734
C
C 115 CHECK TO SEE THAT THE MOUNTAIN RATIO H(J)/A(J) IS LESS THAN 0.6
 115  DZ = H(J)/A(J)
      IF (DZ-0.6)103,116,116
C
C 116 THE MOUNTAIN RATIO H(J)/A(J) IS NOT LESS THAN  0.6
  116 IRROR = 116
      GO TO 7734
C
 104  NMT=J-1
C     NMT                 THE NUMBER OF MOUNTAINS REPRESENTED IN THIS
C                         MOUNTAIN WIND SYSTEM
C 1042  COMPUTE UNPERTURBED VECTOR HERE
C     THE FOLLOWING THREE CARDS CONSTITUTE THE LOCATION COORDINATES OF
C     THE UNPERTURBED WIND VECTOR
      YY=(CRMAXY(K)+CRMINY(K))/2.0
      XX=(CRMAXX(K)+CRMINX(K))/2.0
      ZZ=CRUHT(K)/2.0
      CALL GETWND(XX,YY,ZZ,JWAD,JW)
      IF(JWAD)1043,1044,1045
 1043 IRROR=1043
      GO TO 7734
 1044 IRROR=1044
      GO TO 7734
C     THE FOLLOWING THREE CARDS CONSTITUTE THE MAGNITUDE AND DIRECTION
C     OF THE UNPERTURBED WIND VECTOR
 1045 UO(K)=SQRT(VX(JWAD)*VX(JWAD)+VY(JWAD)*VY(JWAD))
      SN(K)=VY(JWAD)/UO(K)
      CS(K)=VX(JWAD)/UO(K)
      DO 1049 J=1,NMT
 1049 A2H(J)=A2(J)*H(J)*UO(K)
      WRITE (ISOUT,2)K
      WRITE (ISOUT,3)(J,H(J),A(J),XM(J),YM(J),J=1,NMT)
      WRITE (ISOUT,4)CRMAXY(K),CRMINY(K),CRMAXX(K),CRMINX(K),CRGHT(K)   MTWN 177
      WRITE (ISOUT,5)UO(K),SN(K),CS(K)                                  MTWN 178
  105 RETURN                                                            MTWN 179
C                                                                       MTWN 180
C 102 THIS IS THE TESTING AND COMPUTING ROUTE                           MTWN 181
C      COMPUTE THE TOPOGRAPHIC INCREMENT AT POSITION OF THE JTH PARTICLEMTWN 182
C     COMPUTE THE PERTURBED WIND COMPONENTS, SUM THEM, AND ADD THEM     MTWN 183
C     TO THE UNPERTURBED WIND VECTOR.                                   MTWN 184
  102 AX=0.0                                                            MTWN 185
      AY=0.0                                                            MTWN 186
      AZ=0.0                                                            MTWN 187
      DZ=0.0                                                            MTWN 188
      DO 106 I=1,NMT                                                    MTWN 189
C     THE FOLLOWING TWO CARDS TRANSLATE THE PARTICLE INTO THE MOUNTAIN  MTWN 190
C     COORDINATE SYSTEM.                                                MTWN 191
      DELX=XP(J)-XM(I)                                                  MTWN 192
      DELY=YP(J)-YM(I)                                                  MTWN 193
C     THE FOLLOWING TWO CARDS ROTATE THE PARTICLE INTO THE MOUNTAIN     MTWN 194
C     COORDINATE SYSTEM.                                                MTWN 195
      DSX = DELX * CS(K) + DELY * SN(K)                                 MTWN 196
      DSY =-DELX * SN(K) + DELY * CS(K)                                 MTWN 197
      Y2 = DSY * DSY                                                    MTWN 198
      X2 = DSX * DSX                                                    MTWN 199
      R2=X2+Y2                                                          MTWN 200
C     NOW COMPUTE TOPO HEIGHT INCREMENT RESULTING FROM THE ITH MOUNTAIN MTWN 201
C     AND ADD IT TO SUM.                                                MTWN 202
      DZ = DZ + A3H(I)/((A2(I)+R2)*SQRT(A2(I)+R2))                      MTWN 203
C                                                                       MTWN 204
C     COMPUTE PERTURBATION WIND INCREMENTS                              MTWN 205
      AMBDA = ZP(J)+A(I)                                                MTWN 206
      AMBDA2=AMBDA*AMBDA                                                MTWN 207
      DENOM= (R2+AMBDA2)*(R2+AMBDA2)*SQRT(R2+AMBDA2)                    MTWN 208
      Q= A2H(I)*3.0*DSX/DENOM                                           MTWN 209
C                                                                       MTWN 210
C1061   AX, THE PERTURBED WIND COMPONENT IN THE DIRECTION OF THE        MTWN 211
C     UNPERTURBED WIND.                                                 MTWN 212
 1061 AX=AX+A2H(I)*(Y2+AMBDA2-2.0*X2)/DENOM                             MTWN 213
C     AY, AZ, THE PERTURBED WIND COMPONENTS PERPENDICULAR TO THE        MTWN 214
C     DIRECTION OF THE UNPERTURBE) WIND.                                MTWN 215
      AY= AY - Q*DSY                                                    MTWN 216
  106 AZ= AZ - Q*AMBDA                                                  MTWN 217
C                                                                       MTWN 218
C     NOW TEST FOR IMPACTED PARTICLE                                    MTWN 219
      IF(DZ-ZP(J))109,108,108                                           MTWN 220
C 108  PARTICLE HAS IMPACTED                                            MTWN 221
  108 AZ=-1.0E+08                                                       MTWN 222
      AX=0.0                                                            MTWN 223
      AY=0.0                                                            MTWN 224
      GO TO 105                                                         MTWN 225
C 109 THE PARTICLE IS ALOFT.  NOW ADD THE UNPERTURBED  WIND VECTOR TO   MTWN 226
C     THE PERTURBED COMPONENT IN THE SAME DIRECTION.                    MTWN 227
  109 DELX = AX+UO(K)                                                   MTWN 228
C     THE FOLLOWING TWO CARDS DEROTATE THE WIND VECTOR INTO THE         MTWN 229
C     MACRO SYSTEM.                                                     MTWN 230
      AX=DELX*CS(K)-AY*SN(K)                                            MTWN 231
      AY=DELX*SN(K)+AY*CS(K)                                            MTWN 232
      GO TO 105                                                         MTWN 233
      END                                                               MTWN 234
                                                                            235*

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$IBFTC RGWN1   LIST,DECK,M94/2
      SUBROUTINE RGWND1(J,K,AX,AY,AZ)
C     11 OCT 66
C     I. KOHLBERG, T.W.SCHWENKE  TECHNICAL OPERATIONS RESEARCH, INC.
C
C     THIS SUBROUTINE SERVES THE DUAL PURPOSE OF READING RIDGE WIND
C     DATA WHEN THE SIGN OF ARGUMENT J IS MINUS) AND COMPUTING THE
C     RIDGE WIND FOR THE JTH PARTICLE AFTER FIRST CHECKING FOR IMPACT
C     ON THE ANALYTICAL GROUND.  IF IMPACT IS SENSED THE PARTICLE IS
C     ASSIGNED A LARGE DOWNWARD VELOCITY COMPONENT.
C
C ***********************************************************************
C
      COMMON /SET1/
     1          DIAM    , DETID   , IRISE   , IEXEC   , ISIN    , ISOUT    ,
     2          SD      , SPAR    , SSAM    , TME     , TMP1    , TMP2     ,
     3          T2M     , S       , VPR     , W       , X       , Z        ,
     4          WHY     , RMIN    , IDISTR  , SPAR1   , SPAR2   , SPAR3    ,
     5          SPAR4   , SPAR5   , SPAR6   , SPAR7   , SPAR8   , SPAR9
C
C ***********************************************************************
C
      DIMENSION  DETID(12),WHY(40)
      COMMON /SET2/
     1          S       , SUBSID  , GRINT   , BXLL    , BXLU    , BYLL
     2,         BYLU    , TXLL    , TXLU    , TYLL    , TYLU    , XGZ
     3,         YGZ     , NBLCK   , HTOPO   , TTOPO   , ILIM    , JLIM
     4,         KLIM    , II      , JJ      , KK      , XP      , YP
     5,         ZP      , FMAS    , TP      , PS      , VX      , VY
     6,         VZ      , IL      , JL      , IBADD   , WORINT  , NSTRAT
     7,         WLLX    , WLLY    , WORX    , WORY    , BOTHIT  , IPARIN
     8,         IOTOPO  , IOWIND  , IHTOPO  , IPOUT   , IPAROT  , JTOP1
     9,         JWIND1  , IERROR  , TLIMIT  , ENDTIM  , IC      , IBYPAS
     1,         JTOPO   , NLOST   , NG      , NTO     , NTI     , NW
     2,         NALOFT  , DTIME1  , NBMAX   , NFREE   , N       , NCL
     3,         CRMAXY  , CROHT   , NCRTYP  , BZ      , CRMINX  , CRMINY
     4,         UU      , SN      , CS      , NLOCIR  , DTLOC   , ATEMP
     5,         RHO     , NA      , TSZ     , DTMAC   , FROG    , CRMAXX
     6,         ROPART
      DIMENSION TOPOLM(4,4)   ,WINTAR(4)      ,ITOPLM(3,4)
      DIMENSION S(10,10)      ,SUBSID(400)    ,IC(18)
      DIMENSION XP(200)       ,YP(200)        ,ZP(200)        ,FMAS(200)
      DIMENSION TP(200)       ,PS(200)        ,ATEMP(200)     ,RHO(200)
      DIMENSION VX(1500)      ,VY(1500)       ,VZ(1500)       ,IL(70)
      DIMENSION JL(70)        ,IBADD(70)      ,WORX(70)
      DIMENSION WORINT(70)                    ,WLLX(70)       ,WLLY(70)
      DIMENSION WORY(70)      ,BOTHIT(70)     ,SN(6)          ,CS(6)
      DIMENSION CRMINX(6)     ,CRMAXX(6)      ,CRMINY(6)      ,CRMAXY(6)
      DIMENSION CROHT(6)      ,NCRTYP(6)      ,UU(6)
C
C ***********************************************************************
C
C     PARAMETERS PECULIAR TO SUBROUTINE RGWND1
C
      DIMENSION XM(12),YM(12),H(12),A(12),B(12),C(12),SG(12),CG(12),
     1A2(12),AH(12),D(12),A2H(12)
C
C****************************RIDGE WIND 1 GLOSSARY**********************
C
C     A(K)            THE HALF WIDTH OF THE KTH RIDGE
C     AX              WIND VECTOR EAST
```

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C       AY              WIND VECTOR NORTH                                       RGWN  61
C       AZ              VERTICAL WIND VECTOR                                    RGWN  62
C       AX              PERTURBED WIND COMPONENT IN THE DIRECTION OF THE        RGWN  63
C                       UNPERTURBED WIND                                        RGWN  64
C       B(K)            CLOCKWISE ANGULAR DEVIATION OF KTH RIDGE FROM           RGWN  65
C                       TRUE NORTH                                              RGWN  66
C       CCG             COSINE OF ANGLE UNPERTURBED WIND MAKES WITH             RGWN  67
C                       PERPENDICULAR FROM KTH RIDGE                            RGWN  68
C       CN(K)           COSINE OF COUNTER-CLOCKWISE ANGLE FROM EAST OF          RGWN  69
C                       UNPERTURBED WIND                                        RGWN  70
C       CRMAXY(K)       NORTH      BOUNDARY OF THE K-TH LOCAL CELL.             RGWN  71
C       CRMINY(K)       SOUTH      BOUNDARY OF THE K-TH LOCAL CELL.             RGWN  72
C       CRMAXX(K)       EAST       BOUNDARY OF THE K-TH LOCAL CELL.             RGWN  73
C       CRMINX(K)       WEST       BOUNDARY OF THE K-TH LOCAL CELL.             RGWN  74
C       CRUHT(K)        THE LOCAL CELL TOP HEIGHT  (METERS)                     RGWN  75
C       DSX             THE PERPENDICULAR DISTANCE OF THE JTH PARTICLE FROM     RGWN  76
C                       THE ITH RIDGE  (METERS)                                 RGWN  77
C       SZ              SUM OF TOPO HEIGHT INCREMENTS                           RGWN  78
C       DZ              RIDGE RATIO OF H(J)/A(J)                                RGWN  79
C       H(K)            THE HEIGHT OF THE KTH RIDGE                             RGWN  80
C       NRG             NUMBER OF RIDGES IN THIS RIDGE WIND SYSTEM              RGWN  81
C       SN(K)           SINE OF ANGLE COUNTER-CLOCKWISE FROM EAST OF            RGWN  82
C                       UNPERTURBED WIND                                        RGWN  83
C       SSG             SINE OF ANGLE UNPERTURBED WIND MAKES WITH               RGWN  84
C                       PERPENDICULAR FROM KTH RIDGE                            RGWN  85
C       UU(K)           MAGNITUDE OF UNPERTURBED WIND VECTOR                    RGWN  86
C       XM(J)           X LOCATION COORDINATE OF THE J-TH RIDGE                 RGWN  87
C       XX              X COORDINATE OF CENTER OF LOCAL CELL                    RGWN  88
C       YM(J)           Y LOCATION COORDINATE OF THE J-TH RIDGE                 RGWN  89
C       YY              Y COORDINATE OF CENTER OF LOCAL CELL                    RGWN  90
C       ZZ              Z COORDINATE OF CENTER OF LOCAL CELL                    RGWN  91
C       JW              INDEX OF THE WIND STRATUM CONTAINING THE PARTICLE       RGWN  92
C       JWAD            INDEX OF MACRO WIND CELL CONTAINING PARTICLE            RGWN  93
C       XP(J)           PARTICLE POSITION COORDINATE                            RGWN  94
C       YP(J)           PARTICLE POSITION COORDINATE                            RGWN  95
C       ZP(J)           PARTICLE POSITION COORDINATE                            RGWN  96
C                                                                               RGWN  97
C ***********************************************************************RGWN  98
C                                                                               RGWN  99
 1      FORMAT(5F10.3)                                                          RGWN 100
 2      FORMAT(//25X24HLOCAL CIRCULATION NUMBERI6/30X15H  RIDGE  WIND  I//1RGWN 101
     15X5HRIDGE7X5HRIDGE7X5HRIDGE7X20HLOCATION COORDINATES8X15HRIDGE AZIRGWN 102
     2MUTH/15X6HNUMBER8X6HHEIGHT6X5HWIDTH9X1HX11X1HY)                      RGWN 103
 3      FORMAT(/12X,I6,3X,4F12.3,8X,F11.3//)                                    RGWN 104
 4      FORMAT(//25X,36HCOORDINATES OF LOCAL CELL BOUNDARIES/,15X,5HNORTH,RGWN 105
     110X,5HSOUTH,11X,4HEAST,11X,4HWEST,10X,6HHEIGHT//,7X,5F15.3///)     RGWN 106
 5      FORMAT(/25X,46HCHARACTERISTICS OF THE UNPERTURBED WIND VECTOR/20X,RGWN 107
     116HUNPERTURBED WIND,4X,17HCOSINE OF ANGULAR,4X,15HSINE OF ANGULAR,RGWN 108
     2/20X,16HVECTOR MAGNITUDE,5X,15HDEV. FROM NORTH,5X,15HDEV. FROM NORRGWN 109
     3TH//,13X,3F20.5//)                                                      RGWN 110
C                                                                               RGWN 111
C ***********************************************************************RGWN 112
C                                                                               RGWN 113
        DATA PROGRM/6HRGWND1/                                                   RGWN 114
C                                                                               RGWN 115
C ***********************************************************************RGWN 116
C ***********************************************************************RGWN 117
C                                                                               RGWN 118
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```
      IF(J)100,101,102                                                  RGWN 119
 101  IRROR=-101                                                        RGWN 120
 7734 CALL ERROR(PROGRM,IRROR,ISOUT)                                    RGWN 121
C 100 THIS IS THE DATA READING ROUTE                                    RGWN 122
 100  J=0                                                               RGWN 123
      CRUHT(K)=0.0                                                      RGWN 124
 103  J=J+1                                                             RGWN 125
      READ (ISIN,1) XM(J),YM(J),H(J),A(J),B(J)                          RGWN 126
      C(J) = COS(B(J))                                                  RGWN 127
      D(J) = SIN(B(J))                                                  RGWN 128
      A2(J) = A(J)*A(J)                                                 RGWN 129
      A2H(J)=A2(J)*H(J)                                                 RGWN 130
      IF(J-12)1031,1032,1032                                            RGWN 131
 1032 IRROR=1032                                                        RGWN 132
      GO TO 7734                                                        RGWN 133
 1031 IF(H(J))1099,104,1099                                             RGWN 134
C1099 COMPUTE THE KTH LOCAL CELL HEIGHT.                                 RGWN 135
 1099 DZ=ABS(3.0*H(J))                                                  RGWN 136
      IF (DZ-CRUHT(K))110,110,1100                                      RGWN 137
 1100 CRUHT(K)=DZ                                                       RGWN 138
C 110 CHECK TO SEE THAT THE RIDGE JUST READ IS WITHIN THE LIMITS OF     RGWN 139
C     THE KTH LOCAL WIND SYSTEM.                                        RGWN 140
  110 IF(XM(J)-CRMINX(K)) 114,111,111                                   RGWN 141
  111 IF(XM(J)-CRMAXX(K)) 112,112,114                                   RGWN 142
  112 IF (YM(J)-CRMINY(K)) 114,113,113                                  RGWN 143
 113  IF (YM(J)-CRMAXY(K)) 115,115,114                                  RGWN 144
C                                                                       RGWN 145
C 114 THE RIDGE IS NOT WITHIN THE LIMITS OF THE KTH LOCAL WIND SYSTEM   RGWN 146
  114 IRROR= 114                                                        RGWN 147
      GO TO 7734                                                        RGWN 148
C                                                                       RGWN 149
C 115 CHECK TO SEE THAT THE RIDGE RATIO H(J)/A(J) IS LESS THAN 0.6      RGWN 150
 115  DZ = H(J)/A(J)                                                    RGWN 151
      IF (DZ-0.6) 103,116,116                                           RGWN 152
C                                                                       RGWN 153
C 116 THE RIDGE RATIO H(J)/A(J) IS NOT LESS THAN  0.6                   RGWN 154
  116 IRROR = 116                                                       RGWN 155
      GO TO 7734                                                        RGWN 156
C                                                                       RGWN 157
 104  NRG=J-1                                                           RGWN 158
C     NRG                THE NUMBER OF RIDGES REPRESENTED IN THIS       RGWN 159
C                        RIDGE WIND SYSTEM                              RGWN 160
C 1042  COMPUTE UNPERTURBED VECTOR HERE                                 RGWN 161
C     THE FOLLOWING THREE CARDS CONSTITUTE THE LOCATION COORDINATES OF  RGWN 162
C     THE UNPERTURBED WIND VECTOR                                       RGWN 163
      YY=(CRMAXY(K)+CRMINY(K))/2.0                                      RGWN 164
      XX=(CRMAXX(K)+CRMINX(K))/2.0                                      RGWN 165
      ZZ=CRUHT(K)/2.0                                                   RGWN 166
      CALL GETWND(XX,YY,ZZ,JWAD,JW)                                     RGWN 167
      IF(JWAD)1043,1044,1045                                            RGWN 168
 1043 IRROR=1043                                                        RGWN 169
      GO TO 7734                                                        RGWN 170
 1044 IRROR=1044                                                        RGWN 171
      GO TO 7734                                                        RGWN 172
C     THE FOLLOWING THREE CARDS CONSTITUTE THE MAGNITUDE AND DIRECTION  RGWN 173
C     OF THE UNPERTURBED WIND VECTOR                                    RGWN 174
 1045 UU(K)=SQRT(VX(JWAD)*VX(JWAD)+VY(JWAD)*VY(JWAD))                   RGWN 175
      SN(K)=VY(JWAD)/UU(K)                                              RGWN 176
      CS(K)=VX(JWAD)/UO(K)
      DO 1049 J=1,NRG
      SSG   = CS(K)*D(J)+SN(K)*C(J)
      CCG   = CS(K)*C(J)-SN(K)*D(J)
      AH(J)= -A(J)*H(J)*UO(K)*CCG*CCG
      SG(J)=SSG/CCG
 1049 CG(J)= 2.0/CCG
C
      WRITE (ISOUT,2)K
      WRITE (ISOUT,3)(J,H(J),A(J),AH(J),XR(J),YR(J),J=1,NRG)
      WRITE (ISOUT,4)CRMAX(K),CRMIN(K),CMMAXA(K),CSIGMA(K),CSUMT(K)
      WRITE (ISOUT,5)UO(K),SN(K),CS(K)
 105  RETURN
C
C 102 THIS IS THE TESTING AND COMPUTING ROUTE
C      COMPUTE THE TOPOGRAPHIC INCREMENT AT POSITION OF THE JTH PARTICLE
C     COMPUTE THE PERTURBED WIND COMPONENTS, SUM THEM, AND ADD THEM
C     TO THE UNPERTURBED WIND VECTOR.
 102  AX=0.0
      AY=0.0
      AZ=0.0
      DZ=0.0
      DO 106 I=1,NRG
C107  THIS CARD TRANSLATES AND ROTATES THE PARTICLE INTO THE RIDGE
C     WIND SYSTEM.  DSX IS THE PERPENDICULAR DISTANCE OF THE J-TH
C     PARTICLE FROM THE I-TH RIDGE.
 107  DSX = (XP(J)-XR(I))*C(I)-(YP(J)-YR(I))*D(I)
      X2 = DSX*DSX
      AMBDA = ZP(J) +A(I)
      AMBDA2 = AMBDA*AMBDA
C     NOW COMPUTE TOPO HEIGHT INCREMENT RESULTING FROM THE ITH RIDGE
C     AND ADD IT TO SUM.
      DZ= DZ + AZH(I)/(A2(I)+X2)
C
C     THE FOLLOWING CARDS COMPUTE THE PERTURBATION WIND INCREMENTS
      AHCD= AH(I)/((X2+AMBDA2)*(X2+AMBDA2))
      AMBDA2= X2-AMBDA2
C     AX  IS THE COMPONENT IN THE DIRECTION OF THE UNPERTURBED WIND
      AX=AHCD*AMBDA2 + AX
      AY= AHCD*SG(I)*AMBDA2 + AY
 106  AZ= AHCD*CG(I)*AMBDA*DSX + AZ
C
C     NOW TEST FOR IMPACTED PARTICLE
      IF(DZ-ZP(J))109,108,108
C 108  PARTICLE HAS IMPACTED
 108  AZ=-1. E+08
      AX=0.0
      AY=0.0
      GO TO 105
C 109 THE PARTICLE IS ALOFT.  NOW ADD THE UNPERTURBED  WIND VECTOR TO
C     THE PERTURBED COMPONENT IN THE SAME DIRECTION.
 109  DSX=AX+UO(K)
C     THE FOLLOWING TWO CARDS DEROTATE THE WIND SYSTEM INTO MACRO FIELD
C     COORDINATES
      AX= DSX*CS(K)-AY*SN(K)
      AY= DSX*SN(K)+AY*CS(K)
      GO TO 105
      END
                                                                235*

                                                                235 *
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$IBFTC CBRE11  LIST,DECK,M94/2
      SUBROUTINE CBREZ1(J,K,AX,AY,AZ)
C     11 OCT 66
C     I. KOHLBERG, T.W.SCHWENKE  TECHNICAL OPERATIONS RESEARCH, INC.
C     THIS SUBROUTINE SERVES THE DUAL PURPOSE OF READING SEA BREEZE
C     DATA(WHEN THE SIGN OF ARGUMENT J IS MINUS) AND COMPUTING THE
C     SEA BREEZE FOR THE J-TH PARTICLE.
C
C ************************************************************************
C
      COMMON /SET1/
     1          DIAM   , SETID  , IRISE  , IEACC  , IOIN   , ISOUT    ,
     2          SS     , SPAR   , SSAM   , TME    , IMP1   , IMP2     ,
     3          T2M    , U      , VPR    , Y      , X      , Z        ,
     4          AMT    , MAIN   , IDIOTR , SPAR1  , SPAR2  , SPAR3    ,
     5          SPAR4  , SPAR5  , SPAR6  , SPAR7  , SPAR8  , SPAR9
C
C ************************************************************************
C
      DIMENSION  SETID(12),WHY(40)
      COMMON /SET2/
     1          S      , SUBSID , GRINT  , BALL   , BALO   , BTLL
     2,         BYLO   , TALL   , TALO   , TTLL   , TTLO   , ASL
     3,         YOZ    , NBLCK  , MICRO  , ITCRO  , ILIM   , JLIM
     4,         KLIM   , II     , JJ     , KK     , XP     , YP
     5,         ZP     , FRAC   , TP     , PS     , VA     , VT
     6,         VZ     , IL     , JL     , ISADD  , NORIT  , NOTRAT
     7,         WELX   , WELY   , WORX   , WORY   , SCTIMI , IFRAIN
     8,         ISTOPC , ISWIND , IMICRO , IPOOL  , ISKROT , STCP1
     9,         SWINDI , IKNOX  , TLIMIT , ENDTIM , IC     , ISTPAC
     1,         STCPS  , NLOST  , NG     , NTC    ; NTI    , NA
     2,         NALOFT , SITTLI , NDMAX  , NFSEL  , N      , NCL
     3,         CRMAXT , CRCMI  , NCRITH , DZ     , CRMINX , CRMINY
     4,         SO     , SN     , CS     , NEWCIR , STCSS  , ALTMP
     5,         XMU    , NA     , TSL    , STFAC  , FROD   , CRMAXX
     6,         KOPART
      DIMENSION ICPOLM(4,4)    ,NINTAR(4)      ,ITCPLM(3,4)
      DIMENSION S(10,10)       ,SUBSID(400)    ,IC(15)
      DIMENSION XP(200)        ,YP(200)        ,ZP(200)        ,FRAC(200)
      DIMENSION TP(200)        ,PS(200)        ,ALTPM(200)     ,TTC(200)
      DIMENSION VA(1500)       ,VT(1500)       ,VZ(1500)       ,IL(70)
      DIMENSION JL(70)         ,ISADD(70)      ,WORX(70)
      DIMENSION WSPIN(70)                      ,WELX(70)       ,WELY(70)
      DIMENSION WORY(70)       ,SCTIMI(70)     ,SN(5)          ,CS(5)
      DIMENSION CRMINX(5)      ,CRMAXX(5)      ,CRMINY(5)      ,CRMAXT(5)
      DIMENSION CRCMI(6)       ,NCRITH(6)      ,SS(5)
C
C ************************************************************************
C     PARAMETERS  PECULIAR TO CBREZ
      DIMENSION HOZA(9),AOAA(9),FHA(9),RIIA(9),RZIA(9),RINA(9),
     1RZRA(9),CON1A(9),CON2A(9),CANIA(9),CANZA(9),CNNIA(9),
     2CNNZA(9),CMM1A(9),CMMZA(9),CMGA(9),DELTA(9),TAUA(9)
C
C***** ****************SEA BREEZE GLOSSARY********************************
C
C     ACCG           GRAVITATIONAL CONSTANT (METERS/SQR. SECOND)
C     AKT            THERMAL EDDY DIFFUSIVITY (SQR.METERS/ SECOND)
C     AX             WIND VECTOR EAST     (METERS/SECOND)
C     AY             WIND VECTOR NORTH    (METERS/SECOND)
C     AZ             WIND VECTOR VERTICAL  (METERS/SECOND)
C     B              THE ANGLE (MEASURED CLOCKWISE FROM TRUE NORTH) THAT
```

```
C                    DESCRIBES THE ORIENTATION OF THE SHORE LINE.  FOR B  CORE  61
C                    EQUAL TO ZERO,THE SEA IS ON THE LEFT HAND SIDE OF THECORE  62
C                    SHORELINE. (RADIANS)                                 CORE  63
C      BB            A GENERAL PURPOSE VARIABLE USED FOR                  CORE  64
C                       CONSTANT STORAGE IN READ ROUTE,                   CORE  65
C                       WIND VECTOR PERPENDICULAR TO SHORE                CORE  66
C      CROHT         HEIGHT OF THE SEA BREEZE CELL   (METERS)             CORE  67
C      DELTX(N)      MAXIMUM TEMPERATURE DIFFERENTIAL FOR THE NTH         CORE  68
C                    HARMONIC  (DEGREES KELVIN)                           CORE  69
C      ELX           TOTAL EXTENT OF THE SEA BREEZE CELL (METERS)         CORE  70
C      GRAD          INITIAL TEMPERATURE GRADIENT (DEGREES KELVIN /METER) CORE  71
C      NH            NUMBER OF HARMONICS                                  CORE  72
C      GUMA          GULDBERG-MOHN PARAMETER  (1/ SECONDS)                CORE  73
C      SPHI          SINE OF THE LATITUDE OF THE SEA BREEZE CELL          CORE  74
C      TAUX(N)       PHASE LAG OF NTH HARMONIC    (RADIANS)               CORE  75
C      TBAR          AVERAGE GROUND TEMPERATURE (DEGREES KELVIN)          CORE  76
C      XB            A GENERAL PURPOSE VARIABLE USED FOR                  CORE  77
C                       PERPENDICULAR DISTANCE FROM SHORE LINE,           CORE  78
C                       PERPENDICULAR DISTANCE FORM EDGE OF PRIMARY CELL, CORE  79
C                       ATTENUATION CONSTANT                              CORE  80
C                                                                         CORE  81
C************************************************************************CORE  82
C                                                                         CORE  83
 1     FORMAT(4F10.3,I10)                                                 CORE  84
 2     FORMAT(//45X24HLOCAL CIRCULATION NUMBER16/50X12HSEA BREEZE 1/ )    CORE  85
 3     FORMAT(15X4HLINE OF 7X15HGULDBERG-MOHN6X15HNUMBER OF 7X16HTOTAL    CORE  86
      1EXTENT OF5X11HAVG. GROUND/16X8HLATITUDE12X9HPARAMETER7X12H HARMONICORE  87
      2S 5X15HSEA BREEZE CELL5X11HTEMPERATURE/15X9H          10X11H(1/SECORE  88
      3ONDS)50X8H(METERS)2X16H(DEGREES KELVIN)/ 10X2E14.6,4X15,11X,       CORE  89
      4E14.6/// 5X11HATTENUATION5X12HHORIZONTAL EDDY7X15HSHORELINE ANGLE5XCORE  90
      5DIST. INITIAL TEMP.10X5H PHASE ,5X,10H TEMPERATURE /6X8HCONSTANTCORE  91
      6IIX,19HDIFFUSIVITY 7X13HFROM TRUE NORTH6X8HGRADIENT10X,3HLAG,7X10H CORE  92
      7DIFFERENTIAL /5X10H(1/METERS)6X16H(SQ. METERS/SEC.)7X9H(RADIANS)CORE  93
      8X22H(DEGREES KELVIN/METER),5X9H(RADIANS),6X16H(DEGREES KELVIN)/, CORE  94
      9 4E14.6,10X, 9H TAUX(N) ,10X8HDELTX(N),/////)                      CORE  95
 4     FORMAT(2F10.3)                                                     CORE  96
 10    FORMAT(//45X,35HCOORDINATES OF LOCAL CELL BOUNDARIES/,50X,5HNORTH,CORE  97
      110X,5HSOUTH,11X,4HEAST,11X,4HWEST,10X,6HHEIGHT/,22X,5F15.3////)    CORE  98
 21    FORMAT(//23X74H THE NTH HARMONIC CONSTANT COEFFICIENTS USED IN CALCCORE  99
      1ULATING THE WIND FILE///)                                          CORE 100
 22    FORMAT(5X,5H GMGN(,I1,2H)=,E16.8,  5X,5H  AO2(,I1,2H)=,E16.8,      CORE 101
      1        5X,5H  AOX(,I1,2H)=,E16.8,  5X,5H  AOT(,I1,2H)=,E16.8/     CORE 102
      2        5X,5H ANX1(,I1,2H)=,E16.8,  5X,5H ALN1(,I1,2H)=,E16.8,     CORE 103
      3        5X,5H ANX2(,I1,2H)=,E16.8,  5X,5H ALN2(,I1,2H)=,E16.8/     CORE 104
      4        5X,5HSLOW1(,I1,2H)=,E16.8,  5X,5HSLOW2(,I1,2H)=,E16.8,     CORE 105
      5        5X,5H ANN1(,I1,2H)=,E16.8,  5X,5H ANN2(,I1,2H)=,E16.8/     CORE 106
      6        5X,5H PHIN(,I1,2H)=,E16.8,  5X,5H  ENU(,I1,2H)=,E16.8,     CORE 107
      7        5X,5HDELTX(,I1,2H)=,E16.8,  5X,5H TAUX(,I1,2H)=,E16.8///)  CORE 108
C                                                                         CORE 109
C************************************************************************CORE 110
C                                                                         CORE 111
       DATA PROGR/6HCBREZ1/                                               CORE 112
C                                                                         CORE 113
C************************************************************************CORE 114
C************************************************************************CORE 115
C                                                                         CORE 116
       IF(J)100,101,102                                                   CORE 117
 101   IERROR=-101                                                        CORE 118
 7734 CALL ERROR(PROGNM,IRROR,ISOUT)                                      CBRE 119
C 100 THIS IS THE DATA READING ROUTE                                      CBRE 120
C                                                                         CBRE 121.
 100  READ (ISIN,1)SNPHI,SGMA,ELX,THET                                    CBRE 122
      READ (ISIN,1)WW,AKY,G,GRAD,NN                                       CBRE 123
      READ (ISIN,4)(DELTA(N),TAUX(N),N=1,NN)                              CBRE 124
      WRITE (ISOUT,2)K                                                    CBRE 125
      ALM=6.2831853/ELX                                                   CBRE 126
      ALPH=9.8/THET                                                       CBRE 127
      COR=(14.54441E-05)*SNPHI                                            CBRE 128
      DO 2000 N=1,NN                                                      CBRE 129
      OMGX(N)=N                                                           CBRE 130
      OMGX(N)=OMGX(N)*7.27220522E-05                                      CBRE 131
      A2=SGMA*SGMA+OMGX(N)*OMGX(N)                                        CBRE 132
      A1=SQRT(A2)                                                         CBRE 133
      IF(SGMA)1003,1003,1004                                              CBRE 134
C1003 SGMA IS ZERO OR NEGATIVE.  THIS IS NOT ALLOWED                      CBRE 135
 1003 IRROR=1003                                                          CBRE 136
      GO TO 7734                                                          CBRE 137
 1004 T1=-ATAN(OMGX(N)/SGMA)                                              CBRE 138
      T2=-2.0*T1                                                          CBRE 139
      SCC=SGMA**2-OMGX(N)**2+COR**2                                       CBRE 140
      A3=SQRT(SCC**2+4.0*SGMA**2*OMGX(N)**2)                              CBRE 141
      IF(SCC)1005,1055,1555                                               CBRE 142
 1005 T3=ATAN(2.0*OMGX(N)*SGMA/SCC)+3.1415927                             CBRE 143
      GO TO 5555                                                          CBRE 144
 1055 T3=1.5707963                                                        CBRE 145
      GO TO 5555                                                          CBRE 146
 1555 T3=ATAN(2.0*OMGX(N)*SGMA/SCC)                                       CBRE 147
 5555 A4=(A2*ALM**2)/A3                                                   CBRE 148
      T4=T2-T3                                                            CBRE 149
      A5=(A1*ALPH*ALM**2)/A3                                              CBRE 150
      T5=-T1-T3                                                           CBRE 151
      IF(AKY)1006,1006,1606                                               CBRE 152
C1006 AKY IS ZERO OR NEGATIVE.  THIS IS NOT ALLOWED                        CBRE 153
 1006 IRROR=1006                                                          CBRE 154
      GO TO 7734                                                          CBRE 155
 1606 A6=OMGX(N)/AKY                                                      CBRE 156
      A7=GRAD/AKY                                                         CBRE 157
      ACOT4 = A4*COS(T4)                                                  CBRE 158
      ASIT4 = A4*SIN(T4)+A6                                               CBRE 159
      B1=ACOT4*ACOT4-ASIT4*ASIT4-4.0*(A7*A5*COS(T5)-A6*A4*SIN(T4))        CBRE 160
      B2=2.0*ACOT4*ASIT4-4.0*(A6*ACOT4+A5*A7*SIN(T5))                     CBRE 161
      IF(B1)1007,1077,1777                                                CBRE 162
 1007 BETA=ATAN(B2/B1) + 3.1415927                                        CBRE 163
      GO TO 7777                                                          CBRE 164
 1077 IF(B2)4077,9077,9077                                                CBRE 165
 4077 BETA=4.712389                                                       CBRE 166
      GO TO 7777                                                          CBRE 167
 9077 BETA=1.5707963                                                      CBRE 168
      GO TO 7777                                                          CBRE 169
 1777 BETA=ATAN(B2/B1)                                                    CBRE 170
 7777 AM=BETA/2.0                                                         CBRE 171
      B3=(B1*B1+B2*B2)**0.25                                              CBRE 172
      ACOSM=COS(AM)*B3/2.0                                                CBRE 173
      ASINM=SIN(AM)*B3/2.0                                                CBRE 174
      ACOT4=ACOT4/2.0                                                     CBRE 175
      ASIT4=ASIT4/2.0                                                     CBRE 176
      C1= ACOT4+ACOSM                                                   CORE 177
      D1= ASIT4+ASINM                                                   CORE 178
      C2=ACOT4-ACOSM                                                    CORE 179
      D2= ASIT4-ASINM                                                   CORE 180
      IF(C1)1008,1088,1888                                              CORE 181
 1008 GAM1=ATAN(D1/C1) + 3.1415927                                      CORE 182
       GO TO 5888                                                       CORE 183
 1088 IF(D1)9078,9078,9088                                              CORE 184
 9078 GAM1=4.7123890                                                    CORE 185
       GO TO 5888                                                       CORE 186
 9088 GAM1=1.5707963                                                    CORE 187
       GO TO 5888                                                       CORE 188
 1888 GAM1=ATAN(D1/C1)                                                  CORE 189
 5888 IF(C2)1009,1099,1999                                              CORE 190
 1009 GAM2=ATAN(D2/C2) + 3.1415927                                      CORE 191
      GO TO 1111                                                        CORE 192
 1099 IF(D2)9099,9099,4099                                              CORE 193
 9099 GAM2=4.7123890                                                    CORE 194
      GO TO 1111                                                        CORE 195
 4099 GAM2=1.5707963                                                    CORE 196
      GO TO 1111                                                        CORE 197
 1999 GAM2=ATAN(D2/C2)                                                  CORE 198
 1111 SRTE1=(C1*C1+D1*D1)**0.25                                         CORE 199
      SRTE2=(C2*C2+D2*D2)**0.25                                         CORE 200
      AN1=GAM1/2.0                                                      CORE 201
      AN2=GAM2/2.0                                                      CORE 202
      CON1=COS(AN1)                                                     CORE 203
      CON2X(N)=COS(AN2)                                                 CORE 204
      CAN1=SIN(AN1)                                                     CORE 205
      CAN2X(N)=SIN(AN2)                                                 CORE 206
      IF(CON1)5,5,66                                                    CORE 207
 5     R1RX(N)=SRTE1*CON1                                               CORE 208
      R1IX(N)=SRTE1*CAN1                                                CORE 209
      EPS1=1.0                                                          CORE 210
      GO TO 7                                                           CORE 211
 66   R1RX(N)=-SRTE1*CON1                                               CORE 212
      R1IX(N)=-SRTE1*CAN1                                               CORE 213
      EPS1=-1.0                                                         CORE 214
 7    IF(CON2X(N))8,8,9                                                 CORE 215
 8    R2RX(N)= SRTE2*CON2X(N)                                           CORE 216
      R2IX(N)=SRTE2*CAN2X(N)                                            CORE 217
      EPS2=1.0                                                          CORE 218
      GO TO 10                                                          CORE 219
 9    R2RX(N)=-SRTE2*CON2X(N)                                           CORE 220
      R2IX(N)=-SRTE2*CAN2X(N)                                           CORE 221
      EPS2=-1.0                                                         CORE 222
 10   IF(N-1)7730,110,101                                               CORE 223
 7730 IERROR=7730                                                       CORE 224
      GO TO 7734                                                        CORE 225
C DETERMINATION OF HEIGHT OF SEA BREEZE                                  CORE 226
 110  HT1=-1.0/R1RX(N)                                                  CORE 227
      HT2=-1.0/R2RX(N)                                                  CORE 228
C     CRGHT(N) IS THE HEIGHT OF THE SEA BREEZE CELL.                    CORE 229
      IF(HT1-HT2)11,11,12                                               CORE 230
 11   CRGHT(K)=2.0*HT2                                                  CORE 231
      GO TO 13                                                          CORE 232
 12   CRGHT(K)=2.0*HT1                                                  CORE 233
 13   WRITE (IOUT,20)CRMAXY(K),CRMINY(K),CRMAXX(K),CRMINX(K),CRGHT(K)   CORE 234
```

```
      WRITE (IOUT,3)SNPHI,SGMA, NN,ELX,THET,WW,ANT,B,GRAD                CORE 235
      WRITE (IOUT,21)                                                    CORE 236
 131  FAX(N)=T5-AM+TAUX(N)                                               CORE 237
      G=-COR/AI                                                          CORE 238
C                                                                        CORE 239
C     COMPUTATIONS FOR CONSTANT COEFFICIENTS OF THE WIND FIELD           CORE 240
      AJZX(N)=-DELTX(N)*A5/BB                                            CORE 241
      AJXX(N)=AJZX(N)/ALM                                                CORE 242
      AJY=AJXX(N)*G                                                      CORE 243
      ESQ1=EPS1*SRTE1                                                    CORE 244
      ESQ2=EPS2*SRTE2                                                    CORE 245
      AMG=ESQ1/ESQ2                                                      CORE 246
      CNN1X(N)=COS(AN1+T1)*AMG*G                                         CORE 247
      CNN2X(N)=COS(AN2+T1)*G                                             CORE 248
      SNN1X(N)=SIN(AN1+T1)*AMG*G                                         CORE 249
      SNN2X(N)=SIN(AN2+T1)*G                                             CORE 250
      CON1X(N)=CON1*AMG                                                  CORE 251
      CAN1X(N)=CAN1*AMG                                                  CORE 252
      WRITE (IOUT,22) N,OMGX(N),N,AJZX(N),N,AJXX(N),N,AJY,N,R1RX(N),N,R CORE 253
     11IX(N),N,R2RX(N),N,R2IX(N),N,ESQ1,N,ESQ2,N,AN1,N,AN2,N,FAX(N),N,T1CORE 254
     2,N,DELTX(N),N,TAUX(N)                                              CORE 255
 2000 AJXX(N)=AJXX(N)*ESQ2                                               CORE 256
      ELX=ELX/2.0                                                        CORE 257
C1015 COMPUTE CENTER OF SEA BREEZE CELL.                                 CORE 258
 1015 XCB=(CRMAXX(K)+CRMINX(K))/2.0                                      CORE 259
      YCB=(CRMAXY(K)+CRMINY(K))/2.0                                      CORE 260
      COSB=COS(B)                                                        CORE 261
      SINB=SIN(B)                                                        CORE 262
 105  RETURN                                                             CORE 263
C                                                                        CORE 264
C     THIS IS THE COMPUTING ROUTE                                        CORE 265
C                                                                        CORE 266
C102  TEST FOR IMPACTED PARTICLE                                         CORE 267
 102  IF(ZP(J)) 1019,1020,1020                                           CORE 268
 1019 AX=0.0                                                             CORE 269
      AY=0.0                                                             CORE 270
      AZ=-1.0E+8                                                         CORE 271
      GO TO 105                                                          CORE 272
C                                                                        CORE 273
C1020 PARTICLE IS ALOFT                                                  CORE 274
C     THIS CARD ROTATES AND TRANSLATES THE MACRO SYSTEM COORDINATES      CORE 275
C     INTO THE SEA BREEZE CELL CO)RDINATES.                              CORE 276
 1020 XS=(XP(J)-XCB)*COSB-(YP(J)-YCB)*SINB                               CORE 277
      ARG=ALM*XS                                                         CORE 278
C     THE FOLLOWING CARDS ATTENUATE THE WIND FIELD IN THE ADJACENT       CORE 279
C     REGION.                                                            CORE 280
      XS=ELX-ABS(XS)                                                     CORE 281
      IF(XS)130,103 ,103                                                 CORE 282
 130  XS=XS*WW                                                           CORE 283
      GO TO 1030                                                         CORE 284
 103  XS=0.0                                                             CORE 285
 1030 BB=0.0                                                             CORE 286
      AY=0.0                                                             CORE 287
      AZ=0.0                                                             CORE 288
      DO 3000 N=1,NN                                                     CORE 289
C     THE FOLLOWING TEN CARDS COMPUTE WIND FIELD COEFFICIENTS.           CORE 290
      ATTN1=EXP(XS+R1RX(N)*ZP(J))                                        CORE 291
      ATTN2=EXP(XS+R2RX(N)*ZP(J))                                        CORE 292
      AAGG=OMGX(N)*TP(J)+FAX(N)                                         CORE 293
      ARW1=R1IX(N)*ZP(J)+AAGG                                           CORE 294
      ARW2=R2IX(N)*ZP(J)+AAGG                                           CORE 295
      SARW1=SIN(ARW1)*ATTN1                                             CORE 296
      SARW2=SIN(ARW2)*ATTN2                                             CORE 297
      CARW1=COS(ARW1)*ATTN1                                             CORE 298
      CARW2=COS(ARW2)*ATTN2                                             CORE 299
      AAGG=AJXX(N)*COS(ARG)                                             CORE 300
C     THE FOLLOWING FIVE CARDS ARE THE WIND FIELD                       CORE 301
      AZ=AJZX(N)*SIN(ARG)*(CARW1-CARW2) +AZ                             CORE 302
      BB=AAGG*(CARW1*CON1X(N)-SARW1*CAN1X(N)-CARW2*CON2X(N)+SARW2*      CORE 303
     1CAN2X(N)) +BB                                                     CORE 304
 3000 AY=AAGG*  (CARW1*CNN1X(N)-SARW1*SNN1X(N)-CARW2*CNN2X(N)+SARW2*    CORE 305
     1SNN2X(N)) +AY                                                     CORE 306
C15   DEROTATION OF THE WIND VECTORS INTO THE MACROSYSTEM               CORE 307
 15   AX=BB*COSB+AY*SINB                                                CORE 308
      AY=-BB*SINB+AY*COSB                                               CORE 309
      GO TO 105                                                         CORE 310
      END                                                               CORE 311
                                                                           312*

                                                                           312 *
```

```
$IBFTC HEIGH   LIST,DECK,M94/2
      SUBROUTINE HEIGHT(XX,YY,H)
C     11 OCT 66
C     THIS SUBROUTINE RETRIEVES TOPO HEIGHT AT HORIZONTAL COORDINATES
C     XX,YY AND PUTS IT IN H
C
C ***********************************************************************
C
      COMMON /SET1/
     1           DIAM    , DETID   , IRISE   , IEXEC   , ISIN    , ISOUT        ,
     2           SD      , SPAR    , SSAM    , TML     , TMP1    , TMP2         ,
     3           T2M     , U       , VPR     , W       , X       , Z            ,
     4           WHY     , RMIN    , IDISTR  , SPAR1   , SPAR2   , SPAR3        ,
     5           SPAR4   , SPAR5   , SPAR6   , SPAR7   , SPAR8   , SPAR9
      DIMENSION  DETID(12),WHY(40)
C
C ***********************************************************************
C
      COMMON /SET2/
     1           G       , SUBSID  , GRINT   , BXLL    , BXLU    , BYLL
     2,          BYLU    , TXLL    , TXLU    , TYLL    , TYLU    , XGZ
     3,          YGZ     , NSLCK   , HTOPO   , ITOPO   , ILIM    , JLIM
     4,          KLIM    , II      , JJ      , KK      , XP      , YP
     5,          ZP      , PMAS    , TP      , PS      , VX      , VY
     6,          VZ      , IL      , JL      , ISADD   , WGRINT  , NSTRAT
     7,          WLLX    , WLLY    , WORX    , WORY    , BOTHIT  , IPARIN
     8,          IOTOPO  , IOWIND  , ITTOPO  , IPOUT   , IPAROT  , STOP1
     9,          SWIND1  , IRROR   , ILIMIT  , ENDTIM  , IC      , ISYRAS
     1,          STOP3   , NLOST   , NG      , NTO     , NTI     , NW
     2,          NALOFT  , STIME1  , NSMAX   , NFREE   , N       , NCL
     3,          CRMAXY  , CRUMT   , NCRTYP  , SL      , CRMINX  , CRMINY
     4,          UU      , SN      , CS      , NLOCIR  , DTLOC   , ATEMP
     5,          RHO     , NA      , TGZ     , DTMAC   , FROG    , CRMAXX
     6,          ROPART
      DIMENSION TOPOLM(4,4)   ,MINIAR(4)      ,ITOPLM(3,4)
      DIMENSION S(10,10)      ,SUBSID(400)    ,IC(18)
      DIMENSION XP(200)       ,YP(200)        ,ZP(200)        ,PMAS(200)
      DIMENSION TP(200)       ,PS(200)        ,ATEMP(200)     ,RHO(200)
      DIMENSION VX(1500)      ,VY(1500)       ,VZ(1500)       ,IL(70)
      DIMENSION JL(70)        ,ISADD(70)      ,WORX(70)
      DIMENSION WGRINT(70)                    ,WLLX(70)       ,WLLY(70)
      DIMENSION WORY(70)      ,BOTHIT(70)     ,SN(6)          ,CS(6)
      DIMENSION CRMINX(6)     ,CRMAXX(6)      ,CRMINY(6)      ,CRMAXY(6)
      DIMENSION CRUMT(6)      ,NCRTYP(6)      ,UU(6)
C
C ***********************************************************************
C
C     PRESERVE STD GRID INTERVAL
      GRIN=GRINT
C     IS PARTICLE OVER BLOCK OF TOPOGRAPHY NOW IN CORE
      IF(XX-BXLL)4,2,1
    1 IF(XX-BXLU)2,4,4
    2 IF(YY-BYLL)4,11,3
    3 IF(YY-BYLU)11,4,4
C     IS PARTICLE OVER RANGE OF TOPOGRAPHY UNDER STUDY
    4 IF(XX-TXLL)10,6,5
    5 IF(XX-TXLU)6,10,10
    6 IF(YY-TYLL)10,9,7
    7 IF(YY-TYLU)9,10,10
    8 FORMAT (2F12.4)
C     PARTICLE IS BEYOND IN-CORE TOPO SPECIFICATION BUT WITHIN THE TOPO
```

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```
C       SPECIFICATION AREA.  H IS SET   10000.0
    9 H=-10000.0
      GO TO 101
C       PARTICLE IS BEYOND TOPO SPECIFICATION AREA.  H IS SET -20000.0
   10 H=-20000.0
C*********                  TEMP        ***********************************
  101 WRITE(IOUT,8)XX,YY
      GO TO 28
C       FOR PARTICLE OVER TOPO BLOCK NOW IN CORE,FIND COORD OF NEAREST
C       TOPO POINT IN 2 DIM ARRAY (IN NO OF GRINTS FROM LOWER LEFT COR OF
C       BLOCK IN CORE)
   11 I=(XX-BXLL)/GRINT+1.0
      J=(YY-BYLL)/GRINT+1.0
C       H IS TOPO HEIGHT IF SQUARE OF SIDE GRINT TO UPPER RT OF PT(I,J)
C       NOT SUBDIVIDED,A NEG NO IF SUBDIV
      H=S(I,J)
      IF(H)12,28,28
C       SHIFT ORIGIN OF PARTICLE COORD TO LOWER LT OF SQUARE(SIDE,GRINT)
C       UNDER PARTICLE
   12 CI=I
      CJ=J
      CX=XX-BXLL-(CI-1.0)*GRIN
      CY=YY-BYLL-(CJ-1.0)*GRIN
C       DIV SQ GRINT INTO 4 QUADRANTS
      GRIN=GRIN/2.0
C       SHIFT ORIGIN OF PARTICLE COORD TO CENTER OF DIVIDED SQ
      CCX=CX-GRIN
      CCY=CY-GRIN
C       (LOOP STARTS HERE)
C       CONVERT NEG H TO BASE INDEX FOR SUBSID(K)
   13 K=-H+0.5
C       WHICH QUADRANT IS PARTICLE OVER
      IF(CCX)14,15,15
   14 IF(CCY)19,16,16
   15 IF(CCY)17,18,18
C       MODIFY BASE INDEX,REMEMBER QUADRANT
   16 K=K+1
      N=2
      GO TO 20
   17 K=K+3
      N=4
      GO TO 20
   18 K=K+2
      N=3
      GO TO 20
   19 N=1
C       H IS TOPO HT IF QUADRANT NOT SUBDIV IN SUBSID(K),A NEG NO IF DIV
   20 H=SUBSID(K)
      IF(H)21,28,28
C       SUBDIVIDE QUADRANT
   21 GRIN=GRIN/2.0
C       SHIFT ORIGIN OF PARTICLE COORD TO CENTER OF SUBDIVIDED QUADRANT
C       PARTICLE IS OVER
      GO TO(22,24,25,27),N
   22 CCY=CCY+GRIN
   23 CCX=CCX+GRIN
      GO TO 13
   24 CCY=CCY-GRIN
```

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```
      GO TO 23                                                          HEIG 119
   25 CCY=CCY-GRIN                                                      HEIG 120
   26 CCX=CCX-GRIN                                                      HEIG 121
      GO TO 13                                                          HEIG 122
   27 CCY=CCY+GRIN                                                      HEIG 123
      GO TO 26                                                          HEIG 124
   28 RETURN                                                            HEIG 125
      END                                                               HEIG 126
                                                                             127*

                                                                             127 *
```

SAMPLE TEST PROBLEM AND PRINTOUT

The sample printout that follows contains essentially all of the information necessary to reconstruct the inputs that define the atmosphere and wind-field structure. The output has already been described in detail in Table 13.

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                             * * * * * * * * * * *
T H E   D E P A R T M E N T   O F   D E F E N S E   F A L L O U T   P R E D I C T I O N   S Y S T E M
                             * * * * * * * * * * *

                               TRANSPORT MODULE

                                  PREPARED BY
                      TECHNICAL OPERATIONS RESEARCH,INC.
                               BURLINGTON, MASS.

           ****  SUMMARY OF INPUT IDENTIFIERS AND INITIAL CONDITIONS  ****

        ****  INITIAL CONDITIONS (FIREBALL) IDENTIFICATION  ****
         FOURTH LARGE SCALE TEST OF THE DELFIC SYSTEM, 15 NOV. 1966, INIT. COND.

        ****  CLOUD RISE IDENTIFICATION  ****
         FOURTH LARGE SCALE TEST OF THE DELFIC SYSTEM, 15 NOV. 1966,  CLOUD RISE

        ****  PARTICLE SET EXPANSION IDENTIFICATION  ****
         FOURTH LARGE SCALE TEST OF THE DELFIC SYSTEM, 15 NOV. 1966,  PSE

        ****  THIS RUN OF THE TRANSPORT MODULE WAS GIVEN THE FOLLOWING IDENTIFICATION  ****
         FOURTH LARGE SCALE TEST OF THE DELFIC SYSTEM, 15 NOV. 1966,   TRANSPORT

        ****  OTHER INPUT DATA  ****

THE CONTROL VARIABLE ARRAY, IC(J), HAS BEEN GIVEN THE FOLLOWING VALUES.
    1   1   1   0   0   0   1   1   0   0   0   0   0   0   0   0   0   0

THE TRANSPORT TIME LIMIT IS     86400.000

PARTICLE DATA
   DENSITY OF FALLOUT PARTICLES               2600.000  KG/M**3
   IPARIN      1   0.10000E+07   0.10000E+07   0.00000E-38   0.33729E+03          0

TOPOGRAPHIC DATA
    IN THIS RUN WE ASSUME A PLANAR DEPOSITION SURFACE AT ELEVATION   938.174

WIND DATA
    THIS WIND FIELD USES THE FRENCHMAN FLATS AND ROAD 8 STATIONS.  12/20/66
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```
       ATMOSPHERIC PROPERTIES FOR FALL RATE CALCULATION

       HEIGHT OF BOTTOM      VISCOSITY               DENSITY
        OF STRATUM
       METERS ABOVE MSL        (MKS)                  (MKS)

         -0.11000E+04        0.18206E-04          0.13470E+01
         -0.90000E+03        0.18144E-04          0.13219E+01
         -0.70000E+03        0.18082E-04          0.12972E+01
         -0.50000E+03        0.18019E-04          0.12728E+01
         -0.30000E+03        0.17957E-04          0.12487E+01
         -0.10000E+03        0.18514E-04          0.11592E+01
          0.10000E+03        0.18443E-04          0.11466E+01
          0.30000E+03        0.18372E-04          0.11220E+01
          0.50000E+03        0.18301E-04          0.11034E+01
          0.70000E+03        0.18230E-04          0.10847E+01
          0.90000E+03        0.18624E-04          0.10279E+01
          0.11000E+04        0.18452E-04          0.10216E+01
          0.13000E+04        0.18373E-04          0.10064E+01
          0.15000E+04        0.18283E-04          0.99005E+00
          0.17000E+04        0.18180E-04          0.97250E+00
          0.19000E+04        0.18090E-04          0.95639E+00
          0.21000E+04        0.18000E-04          0.94029E+00
          0.23000E+04        0.17905E-04          0.92373E+00
          0.25000E+04        0.17837E-04          0.91509E+00
          0.27000E+04        0.17714E-04          0.89403E+00
          0.29000E+04        0.17616E-04          0.87841E+00
          0.31000E+04        0.17527E-04          0.86372E+00
          0.33000E+04        0.17426E-04          0.84615E+00
          0.35000E+04        0.17329E-04          0.83352E+00
          0.37000E+04        0.17256E-04          0.82046E+00
          0.39000E+04        0.17169E-04          0.80210E+00
          0.41000E+04        0.17094E-04          0.78804E+00
          0.43000E+04        0.17008E-04          0.77388E+00
          0.45000E+04        0.16925E-04          0.75955E+00
          0.47000E+04        0.16891E-04          0.74462E+00
          0.49000E+04        0.16820E-04          0.72667E+00
          0.51000E+04        0.16766E-04          0.71151E+00
          0.53000E+04        0.16723E-04          0.69477E+00
          0.55000E+04        0.16682E-04          0.67882E+00
          0.57000E+04        0.16641E-04          0.66392E+00
          0.59000E+04        0.16558E-04          0.65062E+00
          0.61000E+04        0.16471E-04          0.63732E+00
          0.63000E+04        0.16380E-04          0.62492E+00
          0.65000E+04        0.16290E-04          0.61253E+00
          0.67000E+04        0.16200E-04          0.60013E+00
          0.69000E+04        0.16109E-04          0.58773E+00
          0.71000E+04        0.16039E-04          0.57613E+00
          0.73000E+04        0.15969E-04          0.56457E+00
          0.75000E+04        0.15900E-04          0.55301E+00
          0.77000E+04        0.15820E-04          0.54188E+00
          0.79000E+04        0.15739E-04          0.53079E+00
          0.81000E+04        0.15658E-04          0.51970E+00
          0.83000E+04        0.15577E-04          0.50861E+00
          0.85000E+04        0.15496E-04          0.49752E+00
          0.87000E+04        0.15415E-04          0.48643E+00
          0.89000E+04        0.15334E-04          0.47535E+00
          0.91000E+04        0.15255E-04          0.46455E+00
          0.93000E+04        0.15180E-04          0.45448E+00
          0.95000E+04        0.15105E-04          0.44442E+00
```

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0.97000E+04     0.15029E-04     0.43436E+00
0.99000E+04     0.14954E-04     0.42430E+00
0.10100E+05     0.14879E-04     0.41424E+00
0.10300E+05     0.14804E-04     0.40418E+00
0.10500E+05     0.14729E-04     0.39412E+00
0.10700E+05     0.14656E-04     0.38443E+00
0.10900E+05     0.14587E-04     0.37444E+00
0.11100E+05     0.14520E-04     0.36545E+00
0.11300E+05     0.14461E-04     0.35635E+00
0.11500E+05     0.14414E-04     0.34773E+00
0.11700E+05     0.14368E-04     0.33911E+00
0.11900E+05     0.14322E-04     0.33048E+00
0.12100E+05     0.14275E-04     0.32186E+00
0.12300E+05     0.14229E-04     0.31324E+00
0.12500E+05     0.14183E-04     0.30462E+00
0.12700E+05     0.14136E-04     0.29600E+00
0.12900E+05     0.14090E-04     0.28738E+00
0.13100E+05     0.14044E-04     0.27875E+00
0.13300E+05     0.14060E-04     0.26956E+00
0.13500E+05     0.14087E-04     0.26027E+00
0.13700E+05     0.14091E-04     0.25204E+00
0.13900E+05     0.14053E-04     0.24528E+00
0.14100E+05     0.14035E-04     0.23852E+00
0.14300E+05     0.14006E-04     0.23176E+00
0.14500E+05     0.13978E-04     0.22500E+00
0.14700E+05     0.13950E-04     0.21825E+00
0.14900E+05     0.13921E-04     0.21149E+00
0.15100E+05     0.13893E-04     0.20473E+00
0.15300E+05     0.13905E-04     0.19846E+00
0.15500E+05     0.13926E-04     0.19230E+00
0.15700E+05     0.13948E-04     0.18615E+00
0.15900E+05     0.13970E-04     0.18000E+00
0.16100E+05     0.13992E-04     0.17385E+00
0.16300E+05     0.14014E-04     0.16770E+00
0.16500E+05     0.14036E-04     0.16155E+00
0.16700E+05     0.14053E-04     0.15574E+00
0.16900E+05     0.14055E-04     0.15146E+00
0.17100E+05     0.14052E-04     0.14719E+00
0.17300E+05     0.14051E-04     0.14292E+00
0.17500E+05     0.14050E-04     0.13865E+00
0.17700E+05     0.14050E-04     0.13438E+00
0.17900E+05     0.14049E-04     0.13011E+00
0.18100E+05     0.14048E-04     0.12584E+00
0.18300E+05     0.14057E-04     0.12177E+00
0.18500E+05     0.14100E-04     0.11787E+00
0.18700E+05     0.14133E-04     0.11396E+00
0.18900E+05     0.14166E-04     0.11006E+00
0.19100E+05     0.14200E-04     0.10615E+00
0.19300E+05     0.14233E-04     0.10225E+00
0.19500E+05     0.14266E-04     0.98341E-01
0.19700E+05     0.14299E-04     0.94436E-01
0.19900E+05     0.14314E-04     0.91675E-01
0.20100E+05     0.13970E-04     0.93182E-01
0.20300E+05     0.13994E-04     0.90184E-01
0.20500E+05     0.14018E-04     0.87185E-01
0.20700E+05     0.14042E-04     0.84186E-01
0.20900E+05     0.14067E-04     0.81187E-01
0.21100E+05     0.14089E-04     0.78690E-01
0.21300E+05     0.14111E-04     0.76193E-01
0.21500E+05     0.14133E-04     0.73695E-01
```

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0.21700E+05    0.14155E-04    0.71198E-01
0.21900E+05    0.14177E-04    0.68701E-01
0.22100E+05    0.14199E-04    0.66607E-01
0.22300E+05    0.14221E-04    0.64512E-01
0.22500E+05    0.14242E-04    0.62418E-01
0.22700E+05    0.14264E-04    0.60324E-01
0.22900E+05    0.14286E-04    0.58229E-01
0.23100E+05    0.14308E-04    0.56471E-01
0.23300E+05    0.14329E-04    0.54712E-01
0.23500E+05    0.14351E-04    0.52954E-01
0.23700E+05    0.14373E-04    0.51195E-01
0.23900E+05    0.14394E-04    0.49436E-01
0.24100E+05    0.14416E-04    0.47955E-01
0.24300E+05    0.14438E-04    0.46475E-01
0.24500E+05    0.14459E-04    0.44994E-01
0.24700E+05    0.14481E-04    0.43513E-01
0.24900E+05    0.14502E-04    0.42032E-01
0.25100E+05    0.14524E-04    0.40785E-01
0.25300E+05    0.14545E-04    0.39537E-01
0.25500E+05    0.14567E-04    0.38290E-01
0.25700E+05    0.14588E-04    0.37042E-01
0.25900E+05    0.14610E-04    0.35795E-01
0.26100E+05    0.14631E-04    0.34740E-01
0.26300E+05    0.14653E-04    0.33686E-01
0.26500E+05    0.14674E-04    0.32631E-01
0.26700E+05    0.14696E-04    0.31576E-01
0.26900E+05    0.14717E-04    0.30521E-01
0.27100E+05    0.14738E-04    0.29630E-01
0.27300E+05    0.14760E-04    0.28739E-01
0.27500E+05    0.14781E-04    0.27848E-01
0.27700E+05    0.14802E-04    0.26956E-01
0.27900E+05    0.14824E-04    0.26065E-01
0.28100E+05    0.14845E-04    0.25311E-01
0.28300E+05    0.14866E-04    0.24556E-01
0.28500E+05    0.14887E-04    0.23802E-01
0.28700E+05    0.14909E-04    0.23048E-01
0.28900E+05    0.14930E-04    0.22293E-01
0.29100E+05    0.14951E-04    0.21653E-01
0.29300E+05    0.14972E-04    0.21012E-01
0.29500E+05    0.14993E-04    0.20371E-01
0.29700E+05    0.15015E-04    0.19731E-01
0.29900E+05    0.15036E-04    0.19090E-01
0.30100E+05    0.15057E-04    0.18546E-01
0.30300E+05    0.15078E-04    0.18002E-01
0.30500E+05    0.15099E-04    0.17459E-01
0.30700E+05    0.15120E-04    0.16915E-01
0.30900E+05    0.15141E-04    0.16371E-01
0.31100E+05    0.15162E-04    0.15908E-01
0.31300E+05    0.15183E-04    0.15446E-01
0.31500E+05    0.15204E-04    0.14983E-01
0.31700E+05    0.15225E-04    0.14520E-01
0.31900E+05    0.15246E-04    0.14058E-01
0.32100E+05    0.15270E-04    0.13661E-01
0.32300E+05    0.15295E-04    0.13264E-01
0.32500E+05    0.15319E-04    0.12867E-01
0.32700E+05    0.15343E-04    0.12470E-01
0.32900E+05    0.15367E-04    0.12073E-01
0.33100E+05    0.15392E-04    0.11735E-01
0.33300E+05    0.15417E-04    0.11396E-01
0.33500E+05    0.15442E-04    0.11058E-01
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0.33700E+05    0.15467E-04    0.10719E-01
0.33900E+05    0.15492E-04    0.10381E-01
0.34100E+05    0.15517E-04    0.10093E-01
0.34300E+05    0.15542E-04    0.98043E-02
0.34500E+05    0.15566E-04    0.95159E-02
0.34700E+05    0.15591E-04    0.92276E-02
0.34900E+05    0.15616E-04    0.89392E-02
0.35100E+05    0.15641E-04    0.86931E-02
0.35300E+05    0.15666E-04    0.84471E-02
0.35500E+05    0.15690E-04    0.82010E-02
0.35700E+05    0.15715E-04    0.79549E-02
0.35900E+05    0.15740E-04    0.77089E-02
0.36100E+05    0.15764E-04    0.74988E-02
0.36300E+05    0.15789E-04    0.72887E-02
0.36500E+05    0.15814E-04    0.70785E-02
0.36700E+05    0.15838E-04    0.68684E-02
0.36900E+05    0.15863E-04    0.66583E-02
0.37100E+05    0.15887E-04    0.64785E-02
0.37300E+05    0.15912E-04    0.62986E-02
0.37500E+05    0.15936E-04    0.61187E-02
0.37700E+05    0.15961E-04    0.59388E-02
0.37900E+05    0.15985E-04    0.57590E-02
0.38100E+05    0.16010E-04    0.56048E-02
0.38300E+05    0.16034E-04    0.54506E-02
0.38500E+05    0.16058E-04    0.52963E-02
0.38700E+05    0.16083E-04    0.51421E-02
0.38900E+05    0.16107E-04    0.49879E-02
0.39100E+05    0.16131E-04    0.48557E-02
0.39300E+05    0.16155E-04    0.47234E-02
0.39500E+05    0.16180E-04    0.45911E-02
0.39700E+05    0.16204E-04    0.44588E-02
0.39900E+05    0.16228E-04    0.43265E-02
0.40100E+05    0.16253E-04    0.42128E-02
0.40300E+05    0.16277E-04    0.40990E-02
0.40500E+05    0.16301E-04    0.39853E-02
0.40700E+05    0.16325E-04    0.38715E-02
0.40900E+05    0.16349E-04    0.37578E-02
0.41100E+05    0.16373E-04    0.36598E-02
0.41300E+05    0.16397E-04    0.35619E-02
0.41500E+05    0.16421E-04    0.34639E-02
0.41700E+05    0.16445E-04    0.33660E-02
0.41900E+05    0.16469E-04    0.32680E-02
0.42100E+05    0.16493E-04    0.31837E-02
0.42300E+05    0.16517E-04    0.30993E-02
0.42500E+05    0.16541E-04    0.30149E-02
0.42700E+05    0.16565E-04    0.29305E-02
0.42900E+05    0.16589E-04    0.28461E-02
0.43100E+05    0.16613E-04    0.27732E-02
0.43300E+05    0.16637E-04    0.27004E-02
0.43500E+05    0.16661E-04    0.26275E-02
0.43700E+05    0.16684E-04    0.25546E-02
0.43900E+05    0.16708E-04    0.24817E-02
0.44100E+05    0.16732E-04    0.24187E-02
0.44300E+05    0.16756E-04    0.23557E-02
0.44500E+05    0.16779E-04    0.22927E-02
0.44700E+05    0.16803E-04    0.22297E-02
0.44900E+05    0.16827E-04    0.21667E-02
0.45100E+05    0.16850E-04    0.21122E-02
0.45300E+05    0.16874E-04    0.20576E-02
0.45500E+05    0.16898E-04    0.20031E-02
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                          0.45700E+05          0.16921E-04          0.19486E-02
                          0.45900E+05          0.16945E-04          0.18941E-02
                          0.46100E+05          0.16968E-04          0.18468E-02
                          0.46300E+05          0.16992E-04          0.17995E-02
                          0.46500E+05          0.17016E-04          0.17522E-02
                          0.46700E+05          0.17039E-04          0.17049E-02
                          0.46900E+05          0.17063E-04          0.16576E-02
                          0.47100E+05          0.17072E-04          0.16180E-02
                          0.47300E+05          0.17082E-04          0.15784E-02
                          0.47500E+05          0.17092E-04          0.15389E-02
                          0.47700E+05          0.17102E-04          0.14993E-02
                          0.47900E+05          0.17111E-04          0.14597E-02
                          0.48100E+05          0.17111E-04          0.14258E-02
                          0.48300E+05          0.17111E-04          0.13919E-02
                          0.48500E+05          0.17111E-04          0.13580E-02
                          0.48700E+05          0.17111E-04          0.13240E-02
                          0.48900E+05          0.17111E-04          0.12901E-02
                          0.49100E+05          0.17111E-04          0.12602E-02
                          0.49300E+05          0.17111E-04          0.12302E-02
                          0.49500E+05          0.17111E-04          0.12003E-02
                          0.49700E+05          0.17111E-04          0.11703E-02
                          0.49900E+05          0.17111E-04          0.11403E-02
ENTERING LINK 6

UNDRFLOW AT 54221 IN MU

UNDRFLOW AT 54222 IN MU

UNDRFLOW AT 54222 IN MU

UNDRFLOW AT 54221 IN MU


   THE FOLLOWING WIND VECTORS HAVE BEEN USED TO DEFINE AN ATMOSPHERE UP TO TIME     86400.

            VECTOR        HORIZONTAL COORDINATES         VECTOR COMPONENTS
            HEIGHT          XS            YS            VX          VY          VZ
           975.360    993804.000    999589.641        0.000       0.000       0.000
          1219.200    993804.000    999589.641        0.000       0.000       0.000
          1524.000    993804.000    999589.641        0.000       0.000       0.000
          1828.800    993804.000    999589.641        0.000       0.000       0.000
          2133.600    993804.000    999589.641       -0.860      -0.155       0.000
          2438.400    993804.000    999589.641        2.940       1.070       0.000
          2743.200    993804.000    999589.641        5.420       3.129       0.000
          3048.000    993804.000    999589.641        6.966       4.023       0.000
          3657.600    993804.000    999589.641        3.484       2.011       0.000
          4267.200    993804.000    999589.641        3.484       2.011       0.000
          4876.800    993804.000    999589.641        3.484       2.011       0.000
          5486.400    993804.000    999589.641        7.043      -1.242       0.000
          6096.000    993804.000    999589.641       12.766       2.251       0.000
          1219.200   1026389.000   1019976.125        0.000       0.000       0.000
          1524.000   1026389.000   1019976.125        0.000       0.000       0.000
          1828.800   1026389.000   1019976.125        0.000       0.000       0.000
          2133.600   1026389.000   1019976.125       -1.771       0.249       0.000
          2438.400   1026389.000   1019976.125       -0.981       0.915       0.000
          2743.200   1026389.000   1019976.125        1.447       1.051       0.000
          3048.000   1026389.000   1019975.125        3.484       0.804       0.000
          3352.800   1026389.000   1019976.125        5.312       0.747       0.000
          3657.600   1026389.000   1019976.125        7.082       0.995       0.000
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     3962.400 1026389.000 1019976.125          7.484         1.320        0.000
     4267.200 1026389.000 1019975.125          5.461         1.987        0.000
     4572.000 1026389.000 1019976.125          3.570         2.690        0.000
     4876.800 1026389.000 1019976.125          3.215         3.105        0.000
     5181.600 1026389.000 1019976.125          3.675         3.027        0.000
     5486.400 1026389.000 1019976.125          6.234         0.545        0.000
     5791.200 1026389.000 1019976.125          8.241        -2.055        0.000
     6096.000 1026389.000 1019976.125          9.464        -4.017        0.000

      REQUESTED GRID ARRANGEMENT
    HEIGHT          INTERVAL                              LIMITS
                                   WLLX          WLLY         WURX        WURY
      914.400      4500.000   997750.000    997750.000 1029200.000 1024700.000
     1066.800      4500.000   997750.000    997750.000 1029200.000 1024700.000
     1219.200      4500.000   997750.000    997750.000 1029200.000 1024700.000
     1371.600      4500.000   997750.000    997750.000 1029200.000 1024700.000
     1524.000      4500.000   997750.000    997750.000 1029200.000 1024700.000
     1676.400      4500.000   997750.000    997750.000 1029200.000 1024700.000
     1828.800      4500.000   997750.000    997750.000 1029200.000 1024700.000
     1981.200      4500.000   997750.000    997750.000 1029200.000 1024700.000
     2133.600      4500.000   997750.000    997750.000 1029200.000 1024700.000
     2286.000      4500.000   997750.000    997750.000 1029200.000 1024700.000
     2438.400      4500.000   997750.000    997750.000 1029200.000 1024700.000
     2590.800      4500.000   997750.000    997750.000 1029200.000 1024700.000
     2743.200      4500.000   997750.000    997750.000 1029200.000 1024700.000
     2895.600      4500.000   997750.000    997750.000 1029200.000 1024700.000
     3048.000      4500.000   997750.000    997750.000 1029200.000 1024700.000
     3200.400      4500.000   997750.000    997750.000 1029200.000 1024700.000
     3352.800      4500.000   997750.000    997750.000 1029200.000 1024700.000
     3505.200      4500.000   997750.000    997750.000 1029200.000 1024700.000
     3657.600      4500.000   997750.000    997750.000 1029200.000 1024700.000
     3810.000      4500.000   997750.000    997750.000 1029200.000 1024700.000
     3962.400      4500.000   997750.000    997750.000 1029200.000 1024700.000
     4114.800      4500.000   997750.000    997750.000 1029200.000 1024700.000
     4267.200      4500.000   997750.000    997750.000 1029200.000 1024700.000
     4419.600      4500.000   997750.000    997750.000 1029200.000 1024700.000
     4572.000      4500.000   997750.000    997750.000 1029200.000 1024700.000
     4724.400      4500.000   997750.000    997750.000 1029200.000 1024700.000
     4876.800      4500.000   997750.000    997750.000 1029200.000 1024700.000
     5029.200      4500.000   997750.000    997750.000 1029200.000 1024700.000
     5181.600      4500.000   997750.000    997750.000 1029200.000 1024700.000
     5334.000      4500.000   997750.000    997750.000 1029200.000 1024700.000
     5486.400      4500.000   997750.000    997750.000 1029200.000 1024700.000
     5638.800      4500.000   997750.000    997750.000 1029200.000 1024700.000
     5791.200      4500.000   997750.000    997750.000 1029200.000 1024700.000
     5943.600      4500.000   997750.000    997750.000 1029200.000 1024700.000
     6096.000      4500.000   997750.000    997750.000 1029200.000 1024700.000

COMPUTATION METHOD      1 WAS USED ON THE       4 NEAREST DATA POINTS.


      ALPHA =          457.200METERS.                    BETA =       32000.000METERS.
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WIND COMPONENTS

LEVEL   1        BASE AT        914.400 METERS
EAST-WEST ROW       1
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
EAST-WEST ROW       2
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
EAST-WEST ROW       3
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
EAST-WEST ROW       4
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
EAST-WEST ROW       5
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
EAST-WEST ROW       6
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000

LEVEL   2        BASE AT       1066.800 METERS
EAST-WEST ROW       1
        0    000     0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0    000     0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0    000     0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
EAST-W      ROW     2
        0    000     0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0    000     0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0    000     0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
EAST-W      ROW     3
        0    00      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0    00      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0    00      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
EAST-W      ROW     4
        0     00     0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0     00     0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0     00     0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
EAST-W      ROW     5
        0     00     0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0    000     0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
EAST-WEST ROW       6
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
        0.00000      0.00000      0.00000      0.00000      0.00000      0.00000      0.00000
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LEVEL 35       BASE AT      6090.000 METERS
EAST-WEST ROW     1
     12.76600    12.40726    11.55457    11.25178    10.60150     9.88608     9.26819
     -2.25103    -2.39996    -2.62927    -2.87952    -3.14944    -3.44614    -3.70286
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
EAST-WEST ROW     2
     12.56652    12.01592    11.44111    10.85199    10.26402     9.67492     9.26819
     -2.33381    -2.55317    -2.80093    -3.04540    -3.28952    -3.53404    -3.70286
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
EAST-WEST ROW     3
     12.25293    11.65563    11.06309    10.50159     9.97319     9.47676     9.26818
     -2.46395    -2.71154    -2.95576    -3.19390    -3.41323    -3.61629    -3.70286
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
EAST-WEST ROW     4
     11.94543    11.39031    10.70839    10.17429     9.70388     9.27948     9.26819
     -2.59111    -2.85917    -3.10597    -3.32670    -3.52202    -3.69818    -3.70286
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
EAST-WEST ROW     5
     11.62454    10.92671    10.34295     9.84942     9.43366     9.26819     9.26819
     -2.72477    -3.01362    -3.25675    -3.46160    -3.63418    -3.70286    -3.70286
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
EAST-WEST ROW     6
     11.25204    10.59136     9.93556     9.49012     9.26819     9.26819     9.26819
     -2.87941    -3.14069    -3.42581    -3.61074    -3.70286    -3.70286    -3.70286
      0.00000     0.00000     0.00000     0.00000     0.00000     0.00000     0.00000
ENTERING LINK 7

DAVIES EQUATIONS ARE INACCURATE FOR     12473.701 MICRONS AT       941.347 METERS

DAVIES EQUATIONS ARE INACCURATE FOR     12473.701 MICRONS AT       942.059 METERS

DAVIES EQUATIONS ARE INACCURATE FOR     12473.701 MICRONS AT       943.126 METERS

DAVIES EQUATIONS ARE INACCURATE FOR     12473.701 MICRONS AT       944.703 METERS
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     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
     150     2    50     0     0     0     0     0
     150     2     0     0    50     0     0     0
   ENTERING LINK 5
     142     2    58     0     0     0     0     0

   TRANSPORT IS COMPLETED. INTERMEDIATE RESJLTS ARE ON TAPE  9
   ENTERING LINK 8
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APPENDIX A

THEORY OF OROGRAPHIC FLOW WITH APPLICATION TO TROPOSPHERIC FALLOUT

Introduction

It has been recognized for some time that terrain effects influence the ultimate distribution of local (less than 160 km from blast area) radioactivity resulting from a tropospheric nuclear explosion. The vertical lifting of light debris over mountains can extend the fallout range beyond the usual expectations, while gradual but extended depressions will shorten it. The need to develop a mathematical model for flow over variable terrain, which can be rendered compatible with such systems, arises principally from the lack of sufficient meteorological data at this time to yield a satisfactory time and space dependent picture of the wind field over short distances. Although sounding stations at 14-mi intervals are planned in the near future (Army Integrated Meteorological System), it is questionable whether even this will be sufficient to account for local variations of the wind field. The model of variable terrain flow developed in this investigation is conceived for the purpose of enabling one to predict the wind field in regions where meteorological data are not usually available.

Our model is based upon a perturbation treatment of the usual hydrodynamic-thermodynamic equations assuming an adiabatic atmosphere, and is predicated on the assumption of the existence of a uniform, steady velocity field, $\underset{\sim}{u}_0$, which would otherwise exist in the absence of the ground disturbance. The relationship between the change in the wind field $\Delta \underset{\sim}{v}(x, y, z)$ and the curvature of the terrain is deduced by first deriving the dispersion relationship for the system (which connects the vertical attenuation constant of the velocity field to the periodicity of the ground structure) and subsequently applying the boundary condition that the surface wind trajectory be parallel to the terrain. The resulting expressions become greatly simplified for short wavelengths and when the Coriolis effect is neglected. However, for most practical cases involving tropospheric fallout, the foregoing restrictions are not severe since sounding stations are presumed to exist at reasonable distances from each other.

From a theoretical point of view, this investigation is a modified extension of the earlier work of Queney,[A.1,A.2] but there are differences which render somewhat different results. Although both models utilize perturbation theory to include the effects of variable terrain, there is a distinct conceptual difference between them arising from the choice of the dependent variables. Queney deals with the displaced trajectories of the streamlines as the fundamental physical quantities of interest (which seems to introduce extra degrees of complexity into the problem), while we treat the changes in the velocity field. Our method of attack permits more refined criteria for establishing the validity of the calculation and leads quite naturally to a generalization to three-dimensional systems, which are more frequently encountered than the two-dimensional idealizations of Queney. Moreover, we show that a perturbation theory model for the hydrodynamics does not necessarily imply the applicability of superposition of ground disturbances, a result which does not seem to have been recognized earlier. This is a distinct problem. However, we are able to demonstrate that the superposition hypothesis can serve as the basis of an iterative scheme for computing the velocity field to an arbitrary degree of accuracy consistent with the initial premises of the perturbation method. In certain two-dimensional cases, there does not appear to be much difference between Queney's results and ours.

The overall validity of the model is based upon the applicability of the nonturbulent hydrodynamics equations together with the assumption of an adiabatic atmosphere in the unperturbed state. Consequently, the solutions do not yield lee waves when applied to the assumed small scale disturbances considered in this investigation. In addition, the results are not generally valid in the lower regions of the atmosphere where turbulent boundary layer effects may dominate the physical processes; however, this is not especially important for fallout since uncertainties attributed to lower atmosphere effects will be only a few hundred feet.

Soluble mathematical models of airflow in the troposphere must in some measure be removed from reality because of the enormous complexity of the actual physical system. Despite this inherent limitation, the nonturbulent models of airflow can be useful for fallout calculations if they at least semiquantitatively describe the salient features of the particular aerodynamics. The utility of such models can best be evaluated by comparison with suitable experiments.

Geometric Considerations

For mathematical simplicity the origin is located at a suitable point in the region where the airflow is to be computed. The x axis is established along the unperturbed wind direction, the y axis is perpendicular to the x axis, and the z-axis points in the direction of the zenith. If ϵ denotes the angle between the local west-east direction and the unperturbed wind velocity, then the components of $\underset{\sim}{\Omega}$ are given by

$$\Omega_y = \Omega \cos \Theta \cos \epsilon, \qquad \Omega_x = \Omega \cos \Theta \sin \epsilon, \qquad \Omega_z = \Omega_z ,$$

where Θ is the latitude, and Ω is the sideral day frequency which equals 7.3×10^{-5} sec^{-1}. For our problems all the components of $\underset{\sim}{\Omega}$ are assumed constant (i.e., the curvature of the earth is neglected).

Theory of Airflow

Airflow over variable terrain can be determined by assuming that the changes in wind velocity caused by the ground irregularities are a small perturbation on the wind field. It is postulated that if the ground were flat, the wind velocity, u, would be constant both in position and time. Orographic effects due to mountains and valleys then cause the wind field to change in a determined way as computed from the perturbation theory.

The origin of the coordinate system is established at a suitable point in the vicinity of the region where the wind field is to be computed. Assuming that for all times the thermodynamic process which describes the flow of air is isentropic, the relationship between pressure P and air-mass density ρ is given by

$$\left(P/P_e\right) = \left(\rho/\rho_e\right)^{\gamma} = \left(T/T_e\right)^{\gamma/(1-\gamma)} , \qquad (A.1)$$

where P_e, ρ_e, and T_e are the pressure, mass density, and temperature at the origin in the unperturbed case and $\gamma = 1.4$. These quantities are further related to each other by the ideal gas law,

$$P_e = \left(\rho_e k T_e /m\right) , \qquad (A.2)$$

where k is the Boltzmann constant ($k = 1.38 \times 10^{-16}$ erg deg^{-1}), and m is the mass of the air molecule. The two equations which describe the aerodynamics are the continuity equation and the momentum equation:

$$\partial\rho/\partial t + \nabla \cdot (\rho \underset{\sim}{v}) = 0 \qquad \text{(A.3)}$$

and

$$d\underset{\sim}{v}/dt = 2\underset{\sim}{v} \times \underset{\sim}{\Omega} - \nabla\psi + \underset{\sim}{G} \ , \qquad \text{(A.4)}$$

where $\underset{\sim}{G}$ is the gravity force and is equal to $-G\underset{\sim}{k}$, and ψ is a potential obtained by combining the $(1/\rho)\nabla P$ term with Eq. (A.1).

$$\psi = \left(P_e / \rho_e^{\gamma}\right) [\gamma/(\gamma - 1)] \, \rho^{(\gamma - 1)} \ . \qquad \text{(A.5)}$$

We assume that a steady state exists in which there is only one uniform (spatially homogeneous) component of velocity, u_o, which, by construction, is parallel to the x direction. The system of equations then reduces to

$$0 = -\partial\psi/\partial x, \qquad 0 = -2u_o\Omega_z - \partial\psi/\partial y, \qquad 0 = 2u_o\Omega_y - \partial\psi/\partial z - G \ . \qquad \text{(A.6)}$$

The general solution to Eq. (A.6) is given by

$$\psi = Ay + Bz + \psi_{or} \ , \qquad \text{(A.7)}$$

which when substituted into the foregoing equations gives

$$A = -2u_o\Omega_z, \qquad B = -G + 2u_o\Omega_y \simeq -G \ , \qquad \text{(A.8)}$$

$$\psi_{or} = \gamma/(\gamma - 1) \quad P_e/\rho_e = \gamma/(\gamma - 1) \quad \left(kT_e/m\right) = c_s^2/(\gamma - 1) \ , \qquad \text{(A.9)}$$

where c_s is the speed of sound and equals 3.4×10^4 cm sec^{-1} under STP conditions.

A measure of the distances over which changes in ψ are important in the equilibrium case can be determined by examining the ratios $\psi_{or}/|A| = y_c$ and $\psi_{or}/|B| = z_c$, which are respectively the distances over which the independent changes in ψ equal the value at the origin. We have

$$y_c = \frac{29 \times 10^8}{2u_o \Omega_z} \quad , \tag{A.10}$$

and

$$z_c = \frac{29 \times 10^8}{980} = 3 \times 10^6 \text{ cm} \approx 20 \text{ mi} \quad . \tag{A.11}$$

Using a maximum value of $\Omega_z = \Omega = 7\ 3 \times 10^{-5} \text{ sec}^{-1}$ and a value of $u_o = 4400 \text{ cm sec}^{-1}$ (corresponding to a 100 mph wind) gives a value of $y_c \approx 4.5 \times 10^9$ cm $= 3 \times 10^4$ mi which signifies that.for local fallout variations in y can be neglected altogether in the equilibrium case. This will not be true in general in the perturbed case.

The initial state of the system is thus specified by the velocity

$$\underset{\sim}{v} = \underset{\sim}{i} u_o \tag{A.12}$$

and density

$$\rho = \rho_o(z) = \rho_e \left(1 - z/z_c\right)^{1/(\gamma - 1)} = \rho_e (1 - \alpha z)^{1/(\gamma - 1)} \quad , \tag{A.13}$$

where

$$\alpha = 1/z_c = 1/\left(3 \times 10^6\right) = 0.33 \times 10^{-6} \text{ cm}^{-1} \quad . \tag{A.14}$$

If attention is further confined to the troposphere ($z \leq 2 \text{ mi} = 3.0 \times 10^5$ cm), the variation of density with altitude is approximated by

$$\rho_o(z) \simeq \rho_e \left\{1 - [\alpha/(\gamma - 1)]\ z\right\} = \rho_e (1 - \beta z) \simeq \rho_e\, e^{-\beta z} \quad , \tag{A.15}$$

where β is defined as the tropospheric density attenuation constant,

$$\beta = \alpha/(\gamma - 1) = mG/\gamma kT_e = 2.5\alpha = 0.83 \times 10^{-6}\ \mathrm{cm}^{-1} \ . \tag{A.16}$$

We now assume that the three components of velocity and density become modified by the terrain. The perturbed quantities are assumed to be related to the unperturbed ones by the equations

$$u_p = u_o + \bar{u}, \quad v_p = \bar{v}, \quad w_p = \bar{w}, \quad \rho_p = \rho_o + \bar{\rho}, \quad \psi_p = \psi_o + \bar{\psi} \ . \tag{A.17}$$

Substituting Eq. (A.17) into Eqs. (A.3) and (A.4) and neglecting second order effects, such as $\bar{\rho}\bar{w}$ and $\bar{v}\bar{w}$, gives under stationary conditions $(\partial/\partial t = 0)$

$$\rho_o\left(\frac{\partial\bar{u}}{\partial x} + \frac{\partial\bar{v}}{\partial y} + \frac{\partial\bar{w}}{\partial z}\right) + u_o\frac{\partial}{\partial x}\bar{\rho} + \bar{w}\frac{\partial}{\partial z}\rho_o = 0 \ , \tag{A.18}$$

$$u_o\frac{\partial\bar{u}}{\partial x} = 2\left(\bar{v}\Omega_z - \bar{w}\Omega_y\right) - \frac{\partial\bar{\psi}}{\partial x} \ , \tag{A.19}$$

$$u_o\frac{\partial\bar{v}}{\partial x} = 2\left(\bar{w}\Omega_x - \bar{u}\Omega_z\right) - \frac{\partial\bar{\psi}}{\partial y} \ , \tag{A.20}$$

and

$$u_o\frac{\partial\bar{w}}{\partial x} = 2\left(\bar{u}\Omega_y - \bar{v}\Omega_x\right) - \frac{\partial\bar{\psi}}{\partial z} \ . \tag{A.21}$$

For mathematical convenience, it is desirable to deal with a function, η, related to the initial density ρ_o by the formula

$$\eta = \bar{\rho}/\rho_o \ . \tag{A.22}$$

In terms of η, $\bar{\psi}$ is given by

$$\bar{\psi} = \psi\left(\rho_o + \bar{\rho}\right) - \psi\left(\rho_o\right) = \gamma\left(P_e / \rho_e^{\gamma}\right) \rho_o^{\gamma - 1} \eta \ . \tag{A.23}$$

Using Eq. (A.13) for $\rho_o(z)$ gives

$$\bar{\psi} = \left(\gamma k T_e / m\right)(1 - \alpha z)\eta \ ; \tag{A.24}$$

while the derivatives of $\bar{\psi}$ are

$$\frac{\partial \bar{\psi}}{\partial x} = \frac{\gamma k T_e}{m}(1 - \alpha z) \frac{\partial \eta}{\partial x} \ , \tag{A.25}$$

$$\frac{\partial \bar{\psi}}{\partial y} = \frac{\gamma k T_e}{m}(1 - \alpha z) \frac{\partial \eta}{\partial y} \ , \tag{A.26}$$

and

$$\frac{\partial \bar{\psi}}{\partial z} = -(\gamma - 1) G + \frac{\gamma k T_e}{m}(1 - \alpha z) \frac{\partial \eta}{\partial z} \ . \tag{A.27}$$

The object at this point is to reduce Eqs. (A.18)-(A.21) to a system of linear equations with constant coefficients. This can readily be accomplished by restricting the calculation to values of z much less than z_c so that $(1 - \alpha z) = (1 - z/z_c) \simeq 1$. Also, within this range, $\ln\rho_o = \ln\rho_e - \beta z$, thereby yielding

$$\left(\frac{\partial \bar{u}}{\partial x} + \frac{\partial \bar{v}}{\partial y} + \frac{\partial \bar{w}}{\partial z}\right) + u_o \frac{\partial}{\partial x} \eta - \beta \bar{w} = 0 \ , \tag{A.28}$$

$$u_o \frac{\partial \bar{u}}{\partial x} = 2\left(\bar{v}\Omega_z - \bar{w}\Omega_y\right) - \frac{\gamma k T_e}{m} \frac{\partial \eta}{\partial x} \ , \tag{A.29}$$

$$u_o \frac{\partial \bar{v}}{\partial x} = 2\left(\bar{w}\Omega_x - \bar{u}\Omega_z\right) - \frac{\gamma k T_e}{m} \frac{\partial \eta}{\partial y} \ , \tag{A.30}$$

and

$$u_o \frac{\partial \bar{w}}{\partial x} = 2\left(\bar{u}\Omega_y - \bar{v}\Omega_x\right) + (\gamma - 1)G\eta - \frac{\gamma k T_e}{m} \frac{\partial \eta}{\partial z} \ . \qquad \text{(A.31)}$$

Equations (A.28)-(A.31) relate the perturbed quantities to one another, but the absolute scale of the perturbations must be obtained from the new boundary conditions. We now assume that each of the perturbed quantities can be expressed by an expansion of plane waves.

$$\tilde{u} = \int A(\underset{\sim}{k})\, e^{i\underset{\sim}{k}\cdot\underset{\sim}{r}}\, d^3k, \qquad \tilde{v} = \int B(\underset{\sim}{k})\, e^{i\underset{\sim}{k}\cdot\underset{\sim}{r}}\, d^3k \ ,$$

and (A.32)

$$\tilde{w} = \int C(\underset{\sim}{k})\, e^{i\underset{\sim}{k}\cdot\underset{\sim}{r}}\, d^3k, \qquad \eta = \int D(\underset{\sim}{k})\, e^{i\underset{\sim}{k}\cdot\underset{\sim}{r}}\, d^3k \ ,$$

where $d^3k = dk_x\, dk_y\, dk_z$. Substituting Eq. (A.32) into Eqs. (A.28)-(A.31) leads to the dispersion relationship between the components of the wave vector. Thus, we have

$$\begin{pmatrix} ik_x & ik_y & \left(ik_z - \beta\right) & iu_o k_x \\ ik_x u_o & -2\Omega_z & 2\Omega_y & \left(ik_x G/\beta\right) \\ 2\Omega_z & ik_x u_o & -2\Omega_x & \left(ik_y G/\beta\right) \\ -2\Omega_y & 2\Omega_x & ik_x u_o & \left[(1 - \gamma)G + \left(ik_z G/\beta\right)\right] \end{pmatrix} \begin{pmatrix} A \\ B \\ C \\ D \end{pmatrix} = 0 \ . \qquad \text{(A.33)}$$

The only nontrivial solutions to Eq. (A.33) occur when the determinant of the matrix equals zero. This establishes a connection between k_x, k_y, and k_z. The so-called dispersion relationship can be interpreted in several ways depending on which component(s) of the wave vector $\underset{\sim}{k}$ can be preassigned. It is at this point that the pertinent physical factors are introduced into the problem. Since the topography can be resolved into periodic components of x and y, we must necessarily regard k_x and k_y as real numbers. The dispersion relationship is then interpreted as

$$k_z = k_z\left(k_x, k_y\right) \ . \qquad \text{(A.34)}$$

For each set of values (k_x, k_y) there will be two solutions of Eq. (A.34) that correspond to the roots of the equation which results when the determinant of the matrix Eq. (A.33) is set equal to zero. Since the number of solutions of Eq. (A.34) is finite, we can contract the description of the Fourier components of the field quantities. For example, $\tilde{w}$ now becomes

$$\bar{w}(x,y,z) = \sum_{\mu=1,2} \iint C_\mu\left(k_x, k_y\right) e^{ik_x x} e^{ik_y y} e^{ik_z^\mu\left(k_x, k_y\right)z} \, dk_y \, dk_x \; ;$$

where k_z^μ stands for the μ^{th} root of Eq. (A.34). Setting the determinant of the matrix of Eq. (A.33) equal to zero leads to the dispersion relationship

$$ak_z^2 + b\left(ik_z\right) + c = 0 \;, \tag{A.35}$$

where

$$a = \sigma\left(k_x^2 u_o^2 - \Omega^2 \omega_x^2\right) \;, \tag{A.36a}$$

$$b = \sigma\left[\gamma\beta k_x^2 u_o^2 + 2\Omega k_x k_y u_o \omega_x + \Omega^2\left(2ik_x \omega_z \omega_x + 2ik_y \omega_z \omega_y - \gamma\beta\omega_z^2\right)\right] \;, \tag{A.36b}$$

and

$$\begin{aligned} c = {} & k_x^2 u_o^2\left[\sigma\left(k_x^2 + k_y^2\right) - u_o^2 k_x^2 + (1-\gamma)\sigma\beta^2\right] \\ & + \Omega\beta\sigma\left[2k_x^2 \omega_y u_o - \gamma\left(\omega_y u_o k_x^2 - \omega_x u_o k_x k_y\right)\right] \\ & + \Omega^2\left[4k_x^2 u_o^2 - \sigma\left(k_x \omega_x + k_y \omega_y\right)^2 - \omega_z^2 (1-\gamma)\sigma\beta^2 - \beta\sigma\gamma\left(ik_x \omega_x \omega_y + ik_y \omega_y \omega_z\right)\right] \;, \end{aligned} \tag{A.36c}$$

in which

$$\omega_x = 2\Omega_x/\Omega, \quad \omega_y = 2\Omega_y/\Omega, \quad \omega_z = 2\Omega_z/\Omega, \quad \sigma = (G/\beta) \;. \tag{A.37}$$

Since Eq. (A.33) is homogeneous, the absolute magnitudes of the functions A($\underset{\sim}{k}$), B($\underset{\sim}{k}$), C($\underset{\sim}{k}$), and D($\underset{\sim}{k}$) cannot be determined; only their relationship to each other, as deduced from the boundary conditions, can. For mathematical convenience it is desirable to eliminate D($\underset{\sim}{k}$) and deal only with the Fourier transforms of the velocity components of the wind velocity. Thus, we obtain the equation

$$\begin{pmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{pmatrix} \begin{pmatrix} A \\ B \\ C \end{pmatrix} = 0 \ , \qquad \text{(A 38)}$$

where the b_{ik}'s are the elements of a matrix $\tilde{b}$ and are given by

$$b_{11} = ik_x\xi + iu_o k_x \Omega\omega_y, \quad b_{12} = ik_y\xi - iu_o k_x \Omega\omega_x, \quad b_{13} = (ik_z - \beta)\xi + (u_o k_x)^2$$

$$b_{21} = (ik_x u_o)\xi + ik_x\sigma\Omega\omega_y, \quad b_{22} = -\Omega\omega_z\xi - (ik_x\sigma)\Omega\omega_x, \quad b_{23} = \Omega\omega_y\xi - (ik_x\sigma)(ik_x u_o) ,$$

$$b_{31} = \Omega\omega_z\xi + (ik_y\sigma)\Omega\omega_y, \quad b_{32} = ik_x u_o\xi - (ik_y\sigma)\Omega\omega_x, \quad b_{33} = -\Omega\omega_x\xi + k_x k_y \sigma u_o,$$

$$\text{(A 39)}$$

in which $\xi = (1 - \gamma) G + (ik_z\sigma)$ and $\sigma = (G/\beta)$.

The dispersion relationship derived by setting the determinant of $\tilde{b}$ equal to zero is necessarily the same as that previously derived. Using Eq. (A.38), we deduce the general relationship between the Fourier transforms of the velocity components:

$$A = - \frac{(b_{12}b_{33} - b_{13}b_{32})}{(b_{12}b_{31} - b_{11}b_{32})} C \equiv T(k_x, k_y) \, C(k_x, k_y) \qquad \text{(A 40)}$$

and

$$B = - \frac{(b_{13}b_{31} - b_{11}b_{33})}{(b_{12}b_{31} - b_{11}b_{32})} C \equiv U(k_x, k_y) \, C(k_x, k_y) \ . \qquad \text{(A.41)}$$

Up to this point the analysis has been quite general, but henceforth we shall focus attention in the regime where the Coriolis effect is negligible. This is equivalent to setting $\Omega = 0$. The relationships between the physical parameters which must be satisfied to justify this step for fallout applications is discussed later in this appendix. Setting $\Omega = 0$ in the dispersion relationship gives

$$\sigma k_z^2 + \left(ik_z\right)\sigma\gamma\beta + \sigma\left(k_x^2 + k_y^2\right) - u_o^2k_x^2 + (1 - \gamma)\sigma\beta^2 = 0 \ . \tag{A.42}$$

We now let

$$\lambda = -ik_z \ , \tag{A.43}$$

anticipating an exponential decay with altitude. Since $\sigma = G/\beta = 1.2 \times 10^9 \mathrm{cm}^2 \mathrm{sec}^{-2} >> u_o^2$, we can neglect $u_o^2k_x^2$ in Eq. (A.42) and thus obtain

$$\lambda^2 + \lambda\gamma\beta - k_x^2 - k_y^2 + (\gamma - 1)\beta^2 = 0 \ . \tag{A.44}$$

The roots of Eq. (A.44) are given by

$$\lambda = \frac{-\gamma\beta \pm \left\{(\gamma\beta)^2 + 4\left[k_x^2 + k_y^2 - \beta^2(\gamma - 1)\right]\right\}^{1/2}}{2} \ . \tag{A.45}$$

Since we are primarily interested in short range effects, we shall freely make use of the inequality $k_x^2 + k_y^2 >> \beta^2$ (this implies that the wavelength of the horizontal variations, $2\pi\beta^{-1}$, be less than 50 mi), which yields the following two roots of Eq. (A.45)

$$\lambda = \pm\left(k_x^2 + k_y^2\right)^{1/2} \ , \tag{A.46}$$

where only the positive root is acceptable on physical grounds since this guarantees that the perturbations will dampen at high altitudes. Using the plus root of Eq. (A.46) in Eqs. (A.40) and (A.41) gives

$$T\left(k_x, k_y\right) = -ik_x/\left(k_x^2 + k_y^2\right)^{1/2} \ , \tag{A.47}$$

and

$$U\left(k_x, k_y\right) = -ik_y \Big/ \left(k_x^2 + k_y^2\right)^{1/2} \quad . \tag{A.48}$$

From Eqs. (A.46)-(A.48) we deduce the following expressions for the perturbed velocity components:

$$\bar{w}(x,y,z) = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} C\left(k_x, k_y\right) e^{i\left(k_x x + k_y y\right)} e^{-\left(k_x^2 + k_y^2\right)^{1/2} z} \, dk_x \, dk_y \ , \tag{A.49}$$

$$\bar{u}(x,y,z) = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \left(-ik_x\right)\left(k_x^2 + k_y^2\right)^{-1/2} e^{i\left(k_x x + k_y y\right)} C\left(k_x, k_y\right) e^{-\left(k_x^2 + k_y^2\right)^{+1/2} z} \, dk_x \, dk_y \tag{A.50}$$

and

$$\bar{v}(x,y,z) = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \left(-ik_y\right)\left(k_x^2 + k_y^2\right)^{-1/2} e^{i\left(k_x x + k_y y\right)} C\left(k_x, k_y\right) e^{-\left(k_x^2 + k_y^2\right)^{+1/2} z} \, dk_x \, dk_y \tag{A.51}$$

The function $C(k_x, k_y)$ is determined by application of the perturbed boundary condition. Let

$$\phi(x,y,z) = 0 = z - f(x,y) \tag{A.52}$$

be the equation of the earth's surface. The normal to this surface is $\nabla\phi$:

$$\nabla\phi = -\underset{\sim}{i}\,\frac{\partial f}{\partial x} - \underset{\sim}{j}\,\frac{\partial f}{\partial y} + \underset{\sim}{k} \quad . \tag{A.53}$$

On physical grounds, we must necessarily demand that the wind velocity be parallel to the surface $z = f(x,y)$ at every point. Thus, the boundary conditions are mathematically stated as

$$\begin{aligned} \left[\left(\underset{\sim}{v} \cdot \nabla\phi\right)\right] &= 0 \\ &\text{along } z = f(x,y) \ , \end{aligned} \tag{A.54}$$

where

$$\underset{\sim}{v} = \underset{\sim}{i}u + \underset{\sim}{j}v + \underset{\sim}{k}w = \underset{\sim}{i}u_o + (\underset{\sim}{i}\bar{u} + \underset{\sim}{j}\bar{v} + \underset{\sim}{k}\bar{w}) \ . \tag{A.55}$$

Inserting Eq. (A.55) into Eq. (A.54) gives

$$\bar{w}(x, y, z = f) = u_o\left(\frac{\partial f}{\partial x}\right) + \bar{u}(x, y, z = f)\left(\frac{\partial f}{\partial x}\right) + \bar{v}(x, y, z = f)\left(\frac{\partial f}{\partial y}\right) \ . \tag{A.56}$$

Using Eqs. (A.47)-(A.51) in Eq. (A.56) yields the following integral equation for $C(k_x, k_y)$:

$$\int_{k_x}\int_{k_y}\left[1 - T\left(k_x, k_y\right)\left(\frac{\partial f}{\partial x}\right) - U\left(k_x, k_y\right)\left(\frac{\partial f}{\partial y}\right)\right]$$

$$C\left(k_x, k_y\right) e^{ik_x x} e^{ik_y y} e^{\left[-\left(k_x^2 + k_y^2\right)^{1/2} f(x, y)\right]} dk_x \, dk_y$$

$$= u_o \int_{k_x}\int_{k_y} \left(ik_x\right) F\left(k_x, k_y\right) e^{ik_x x} e^{ik_y y} dk_x \, dk_y \ , \tag{A.57}$$

where

$$F\left(k_x, k_y\right) = \left(\frac{1}{2\pi}\right)^2 \iint f(x, y) \, e^{-ik_x x} e^{-ik_y y} dx \, dy \ ,$$

and (A.58)

$$f(x, y) = \iint F\left(k_x, k_y\right) e^{ik_x x} e^{ik_y y} dk_x \, dk_y \ .$$

The solution for $C(k_x, k_y)$ is impossible to achieve by direct means because of the dependence of the integration of the left-hand side of Eq. (A.57) on f(x, y) and on the derivatives of $f(x, y)$. However, a systematic perturbation method for computing $C(k_x, k_y)$ can be deduced. The approximation to $C(k_x, k_y)$, achieved by setting $\exp - \left[\left(k_x^2 + k_y^2\right)^{1/2} f(x, y)\right]$ equal to unity, is equivalent to assuming that the maximum elevation, f_{max}, is small compared to the wavelength of the horizontal oscillation, or in simpler terms the slope of the terrain is small. On the other hand, the neglect of $\bar{u}(\partial f/\partial x)$ as compared to $u_o(\partial f/\partial x)$ is necessarily consistent with the initial premise of the perturbation method used in this analysis, namely that the change in the velocity field be small compared to the initial velocity. This obviously must apply when comparing $\bar{u}$ to u_o. The neglect of $\bar{v}(\partial f/\partial y)$ as compared to $u_o(\partial f/\partial x)$ is somewhat difficult to justify under all cases. Although $\bar{v}$ is assumed small compared to u_o, we must also be sure that $(\partial f/\partial y)$ is not substantially greater than $(\partial f/\partial x)$.

The apriori assumption

$$\bar{u}\left(\frac{\partial f}{\partial x}\right) + \bar{v}\left(\frac{\partial f}{\partial y}\right) < u_o\left(\frac{\partial f}{\partial x}\right) \tag{A.59}$$

is equivalent to neglecting $-T(\partial f/\partial x) - U(\partial f/\partial y)$ as compared to unity in Eq. (A.57). The systematic method for computing $C(k_x, k_y)$ is based upon Eq. (A.59) coupled with the previously mentioned approximation

$$\exp\left[-\left(k_x^2 + k_y^2\right)^{1/2} f(x, y)\right] \equiv \Gamma \approx 1 \ . \tag{A.60}$$

Introduction of the functions

$$\xi = 1 - \Gamma = - \sum_{n=1} \frac{\phi^n}{n!} \ , \tag{A.61}$$

where

$$\phi = -\left(k_x^2 + k_y^2\right)^{1/2} f(x, y) \ , \tag{A.62}$$

and

$$\tau = T\left(k_x, k_y\right)\left(\frac{\partial f}{\partial x}\right) + U\left(k_x, k_y\right)\left(\frac{\partial f}{\partial y}\right) \tag{A.63}$$

permits Eq. (A.57) to be written as

$$\int C(\underset{\sim}{k})\, e^{i\underset{\sim}{k}\cdot\underset{\sim}{r}}\, d\underset{\sim}{k} = u_o \int H(\underset{\sim}{k})\, e^{i\underset{\sim}{k}\cdot\underset{\sim}{r}}\, d\underset{\sim}{k} + \int \Delta C(\underset{\sim}{k})\, e^{i\underset{\sim}{k}\cdot\underset{\sim}{r}}\, d\underset{\sim}{k} \,. \tag{A.64}$$

where

$$\Delta = (\tau + \xi - \xi\tau) = \Delta(\underset{\sim}{k}, x, y), \quad H(\underset{\sim}{k}) = ik_x F(\underset{\sim}{k}), \quad \underset{\sim}{k} = \underset{\sim}{i} k_x + \underset{\sim}{j} k_y, \quad d\underset{\sim}{k} = dk_x\, dk_y \;.$$

Multiplying Eq. (A.64) by exp $(-i\underset{\sim}{k}' \cdot \underset{\sim}{r})$, and then integrating over $\underset{\sim}{r}$, gives

$$C(\underset{\sim}{k}') = u_o H(\underset{\sim}{k}') + \left(\frac{1}{2\pi}\right)^2 \int_{\underset{\sim}{k}} \int_{\underset{\sim}{r}} \Delta(\underset{\sim}{k}, \underset{\sim}{r})\, C(\underset{\sim}{k})\, e^{i(\underset{\sim}{k} - \underset{\sim}{k}')\cdot\underset{\sim}{r}}\, d\underset{\sim}{k}\, d\underset{\sim}{r} \;. \tag{A.65}$$

The perturbation scheme is developed by regarding the second term on the right-hand side of Eq. (A.65) as small. The first approximation to $C(\underset{\sim}{k})$, denoted by $C^{(1)}$, is deduced by completely disregarding the second term of the right-hand side. Thus

$$C^{(1)}(\underset{\sim}{k}') = u_o H(\underset{\sim}{k}') = u_o\left(ik'_x\right) F(\underset{\sim}{k}') \;. \tag{A.66}$$

Since F(k) is the sum of individual contributions to the topography, we see that the principle of linear superposition is also reflected in $C^{(1)}(k)$. The second approximation is obtained by using Eq. (A.66) for $C(\underset{\sim}{k})$ in the integral expression

$$C^{(2)}(\underset{\sim}{k}') = u_o H(\underset{\sim}{k}') + \left(\frac{1}{2\pi}\right)^2 \int_{\underset{\sim}{k}} \int_{\underset{\sim}{r}} \Delta(\underset{\sim}{k}, \underset{\sim}{r}) \left[u_o H(\underset{\sim}{k})\right] e^{i(\underset{\sim}{k} - \underset{\sim}{k}')\cdot\underset{\sim}{r}}\, d\underset{\sim}{k}\, d\underset{\sim}{r} \;. \tag{A.67}$$

It follows by inspection that the nth approximation to $C(\utilde{k})$ is given by

$$C^{(n)}(\utilde{k}') = u_o H(\utilde{k}') + \left(\frac{1}{2\pi}\right)^2 \int_{\utilde{k}} \int_{\utilde{r}} \Delta(\utilde{k}, \utilde{r})\, C^{(n-1)}(k)\, e^{i(\utilde{k} - \utilde{k}')\cdot \utilde{r}}\, d\utilde{k}\, d\utilde{r} \quad , \tag{A.68}$$

with

$$C^{(0)} = 0 \quad .$$

The corresponding Fourier transforms of the perturbed x and y components of the wind field, $A(\utilde{k})$ and $B(\utilde{k})$ respectively, are found from Eqs. (A.40) and (A.41) to the same order of approximation. The ultimate validity of this perturbation method can be evaluated only posteriorly — by comparing the calculated change in the magnitude of the wind field with u_o. Mathematically, the developed theory is valid so long as

$$\bar{u}^2 + \bar{v}^2 + \bar{w}^2 < u_o^2 \quad . \tag{A.69}$$

The prescription for calculating the wind field due to terrain effects is summarized as follows. Equation (A.68) is used to compute the Fourier transform of the vertical wind. The Fourier transform of the change in the horizontal components of the wind field is then determined by Eqs. (A.40) and (A.41). Finally, the inversion formula is employed to compute $\bar{u}(\utilde{r})$, $\bar{v}(\utilde{r})$, and $\bar{w}(\utilde{r})$.

The value of computing $C(\utilde{k})$ beyond the first approximation is worthwhile, even though the hydrodynamics model considers only the first correction to the flow, because the iteration scheme can more precisely establish the range of validity of the first approximation to $C(\utilde{k})$ and the dependence of $C(\utilde{k})$ on the characteristic features of the terrain. Most topography is complex and, as such, cannot always be represented by a simple periodic structure, but rather by a sum of frequencies. The higher corrections to $C(\utilde{k})$ take into account the interaction between the Fourier components of the ground structure and, consequently, must be evaluated to more firmly establish the validity of the superposition principle implicit in the first approximation.

In the next section, we shall apply the first-order theory to compute changes in the wind field caused by specific orographic effects. However, now we shall consider a simple two dimension periodic structure to exhibit the method for computing higher order corrections to $C(\underset{\sim}{k})$.

Let

$$f(x) = h\, e^{ik_o x} \,, \tag{A.70}$$

from which we have:

$$F(k) = \frac{h}{2\pi} \int e^{ik_o x} e^{-ikx}\, dx = h\delta\left(k - k_o\right) \tag{A.71}$$

and

$$C^{(1)}(k) = iku_o h\delta\left(k - k_o\right) = iu_o\left(k_o h\right)\, \delta\left(k - k_o\right) \,, \tag{A.72}$$

where $\delta(k)$ is the Dirac delta function. This yields

$$\bar{w}(x, z) = \int iku_o h\delta\left(k - k_o\right) e^{ikx} e^{-|k|z}\, dk = ik_o hu_o\, e^{ik_o x}\, e^{-|k_o|z} \,. \tag{A.73}$$

Since $T(k_x, k_y = 0) = -ik/|k|$, it follows that

$$\bar{u}(x, z) = +u_o\left(|k_o|h\right) e^{ik_o x}\, e^{-|k_o|z} \,. \tag{A.74}$$

Within the confines of the first approximation the inequality of Eq. (A.69) reduces to

$$(2)^{1/2}\left(|k_o|h\right) << 1 \,, \tag{A.75}$$

which basically shows that the slope of the terrain must be less than unity. The second approximation to $C(\underset{\sim}{k})$ is given by

$$C^{(2)}(\underset{\sim}{k'}) = iu_o\left(k_o h\right)\delta\left(k' - k_o\right) + \left(\frac{1}{2\pi}\right)\int_k\int_x \Delta(k, x)\left[iu_o\left(k_o h\right)\delta\left(k - k_o\right)\right] e^{i(k - k')}\, dk\, dx \,, \tag{A.76}$$

where

$$\Delta(k,x) = T(k)\left(\frac{\partial f}{\partial x}\right) - \sum_{n=1}^{\infty} \frac{(-1)^n}{n!} (|k|f)^n + T(k)\left(\frac{\partial f}{\partial x}\right) \sum_{n=1}^{\infty} \frac{(-1)^n}{n!} (|k|f)^n \,. \tag{A.77}$$

Inserting Eq. (A.77) into Eq. (A.76) and performing the integration over k and x gives the following expression for $C^{(2)}(k')$:

$$\begin{aligned} C^{(2)}(k') = {} & iu_o\left(k_o h\right) \delta\left(k' - k_o\right) + iu_o\left(k_o h\right)^2 \delta\left(k' - 2k_o\right) \operatorname{sgn}\left(k_o\right) \\ & - iu_o\left(k_o h\right) \sum_{n=1}^{\infty} \frac{(-1)^n}{n!} \left(|k_o|h\right)^n \delta\left[k' - (n+1)k_o\right] \\ & + iu_o\left(k_o h\right)^2 \operatorname{sgn}\left(k_o\right) \sum_{n=1}^{\infty} \frac{(-1)^n}{n!} \left(|k_o|h\right)^n \delta\left[k' - (n+2)k_o\right] , \end{aligned} \tag{A.78}$$

where

$$\operatorname{sgn}\left(k_o\right) \equiv |k_o| / k_o \,.$$

It is easy to show that the vertical component of velocity corresponding to $C^{(2)}(k')$ is given by

$$\begin{aligned} \bar{w}(x,z) = {} & iu_o\left(k_o h\right) \exp\left(ik_o x - |k_o|z\right)\left\{2 - \exp\left[-|k_o|h \exp\left(ik_o x - |k_o|z\right)\right]\right]\right\} \\ & + \operatorname{sgn}\left(k_o\right) iu_o\left(k_o h\right)^2 \exp\left[2\left(ik_o x - |k_o|z\right] \exp\left[-|k_o|h \exp\left(ik_o x - |k_o|z\right)\right] . \end{aligned} \tag{A.79}$$

Examination of the second term in Eq. (A.79) shows that the uncertainties introduced in the computation of $\bar{w}(x,z)$ by neglecting higher order terms are of the order of $(k_o h)^2$ for a one-dimensional periodic structure. The degree of accuracy to which one may choose to compute the velocity field for fallout computations should be consistent with the uncertainties introduced in other aspects of the calculation.

Application of the Theory to Specific Geometries

In this section we shall apply the theory to an infinite mountain ridge which makes an arbitrary angle with respect to the unperturbed flow, and to a mountain. Within the context of the theory a valley may be considered as an inverted mountain or mountain ridge. We have chosen these particular models because the terrain can be mathematically interpreted as a superposition of mountains and mountain ridges, and hence the general solution of airflow over variable terrain can be determined by superimposing the solutions for individual mountains, valleys, and ridges.

Mountain Ridge Not Perpendicular to Unperturbed Flow

In this case, the perpendicular to the line depicting the crest of the mountain makes an angle γ with respect to the direction of flow, as shown in Figure A.1.

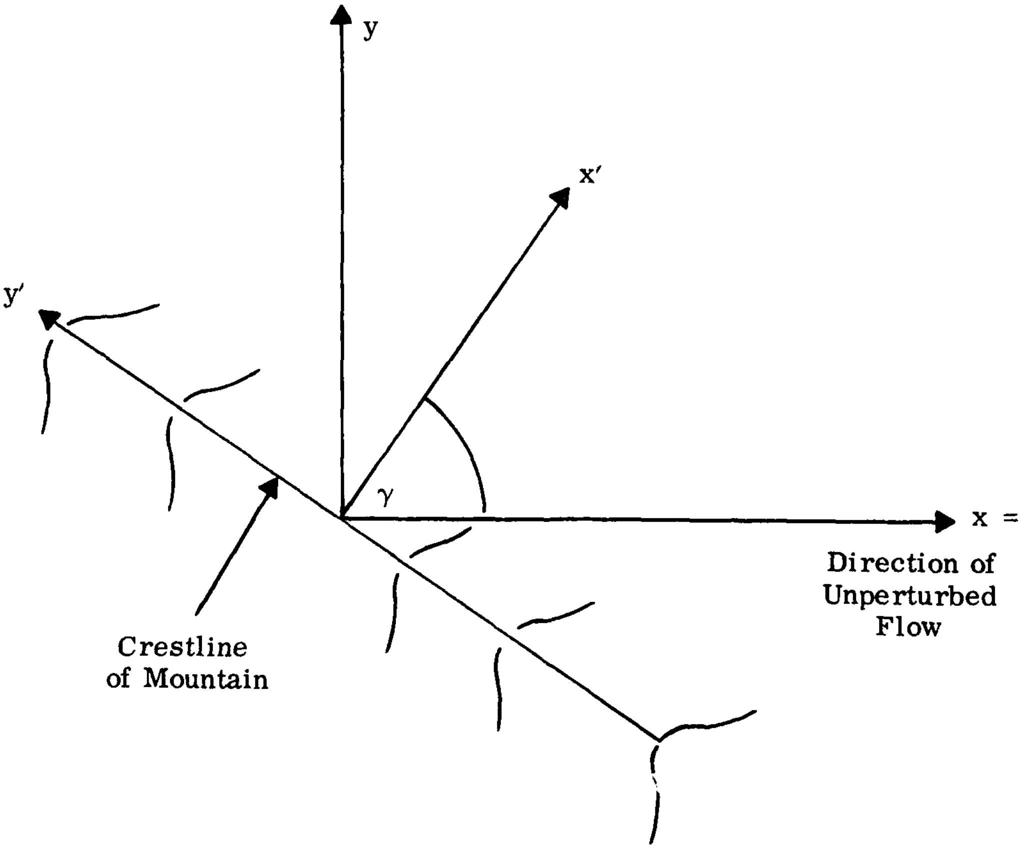


Figure A.1. Mountain Ridge Not Perpendicular to Flow

A suitable mathematical representation of a mountain ridge when viewed along the y' axis has been deduced by Queney[A.2] who showed that the topography could be represented by the equation

$$z = f'(x', y') = \frac{h}{1 + (x'/a)^2} , \tag{A.80}$$

which as observed is independent of y'. However, the transformation equations

$$x = x' \cos\gamma - y' \sin\gamma, \qquad y = x' \sin\gamma + y' \cos\gamma \tag{A.81}$$

show that the topographical description in the x, y system, namely

$$f(x, y) = f'[x'(x, y), y'(x, y)] , \tag{A.82}$$

will be a function of both x and y. The Fourier transform of the mountain ridge function in our system is

$$F(k_x, k_y) = \left(\frac{1}{2\pi}\right)^2 \iint f(x, y)\, e^{-ik_x x - ik_y y}\, dx\, dy . \tag{A.83}$$

However, since $\underset{\sim}{k} \cdot \underset{\sim}{r}$ is invariant under an orthogonal transformation, we have

$$F(k_x, k_y) = F'\left[k'_x(k_x, k_y), k'_y(k_x, k_y)\right] = \left(\frac{1}{2\pi}\right)^2 \iint f'(x', y')\, e^{-ik'_x x' - ik'_y y'}\, dx'\, dy' , \tag{A.84}$$

where

$$k_x = k'_x \cos\gamma - k'_y \sin\gamma, \qquad k_y = k'_x \sin\gamma + k'_y \cos\gamma . \tag{A.85}$$

When Eq. (A.80) is inserted in Eq. (A.84) we obtain

$$F'(k'_x, k'_y) = \left(\frac{ah}{2}\right) e^{-|k'_x| a}\, \delta(k'_y) . \tag{A.86}$$

Using the inversion formula with $C(k_x, k_y) = ik_x u_o F(k_x, k_y)$ yields the following expression for $\bar{w}(x, y, z)$:

$$\bar{w}(x,y,z) = u_o \iint \left(ik_x\right) e^{ik_x x} e^{ik_y y} F\left(k_x, k_y\right) e^{-\left(k_x^2 + k_y^2\right)^{1/2} z} dk_x \, dk_y$$

$$= u_o \frac{\partial}{\partial x} \iint e^{i\left(k'_x x' + k'_y y'\right)} F'\left(k'_x, k'_y\right) e^{-\left(k'^{2}_x + k'^{2}_y\right)^{1/2} z} dk'_x \, dk'_y \quad . \qquad \text{(A.87)}$$

Using Eq. (A.86) permits integration of Eq. (A.87) and we thus obtain

$$\bar{w}(x,y,z) = -2u_o(ah)\,\lambda \cos\gamma \frac{x'}{\left(x'^2 + \lambda^2\right)^2} \quad , \qquad \text{(A.88)}$$

where

$$x' = x \cos\gamma + y \sin\gamma \quad ,$$

and (A.89)

$$\lambda = z + a \quad .$$

It is also easy to show that the x and y components of the perturbed velocity field are given by

$$\bar{u}(x,y,z) = -u_o(ah) \cos^2\gamma \left[\left(x'^2 - \lambda^2\right)/\left(x'^2 + \lambda^2\right)^2\right] \quad , \qquad \text{(A.90)}$$

and

$$\bar{v}(x,y,z) = -u_o(ah) \cos\gamma \sin\gamma \left[\left(x'^2 - \lambda^2\right)/\left(x'^2 + \lambda^2\right)^2\right] \quad . \qquad \text{(A.91)}$$

Since $\bar{u}$, $\bar{v}$, and $\bar{w}$ depend only on x', the origin of the system can conveniently be located anywhere along the crestline

An assessment of the range of validity of the theory can be rendered by examining the ratio, r, of the magnitude of the perturbed velocity to u_o when the flow is perpendicular to the crestline (i.e., $\gamma = 0$). In this case we have

$$\left(|\Delta \underset{\sim}{v}|/u_o\right) = \left(\bar{u}^2 + \bar{w}^2\right)^{1/2} /u_o = r = ah/\left[x^2 + (z + a)^2\right] , \qquad (A.92)$$

where the altitude z is defined in the range $z \geq f(x) = h/(1 + (x/a)^2)$. For a preassigned value of the half width, a, the requirement that r be much less than unity over all space establishes an upper bound to h which will render the results consistent with the perturbation theory. A good measure of this upper limit can be obtained by evaluating r at the top of the ridge ($x = 0$, $z = h$). Thus we have

$$r_t = ah/(h + a)^2 = (h/a)/\left[1 + (h/a)^2\right] . \qquad (A.93)$$

Examination of the foregoing expression shows that r_t is less than unity regardless of the ratio (h/a). Thus one would conclude that the first-order perturbation theory would work under all cases, even including an infinitely steep mountain ridge. This obviously cannot be the case. Apparently, higher order corrections as computed by the iteration scheme are necessary to establish by analytical techniques the range of validity of the calculation. As we shall show in the next section, however, the limitations of the first-order theory can also be assessed by graphical means; that is, by examination of the computed wind streamlines.

It is interesting to note in passing that when the theory is applied to a valley, in which case h is replaced by $-|h|$ and the ratio, r, is computed at the bottom of the valley ($x = 0$, $z = -|h|$), we obtain

$$r_b = a|h|/(a - |h|)^2 , \qquad (A.94)$$

which clearly shows that the theory is valid only for a small slope, $|h| < a$.

A Single Mountain

Investigations have shown that a suitable repr^esentation for a mountain is

$$z = f(x, y) = \frac{h\left(a^3\right)}{\left(a^2 + r^2\right)^{3/2}} = \frac{A}{\left(a^2 + r^2\right)^{3/2}} , \qquad (A.95)$$

where h is the maximum elevation of the mountain, $r^2 = x^2 + y^2$, and a is its characteristic dropoff rate (when r = a, f = 0.35 h).

Although one can construct several mountain functions which are similar to f(x, y), this particular function was selected because it ultimately yields analytic expressions for the perturbed components of the wind field. The Fourier transform of f(x, y) is

$$F\left(k_x, k_y\right) = \frac{A}{(2\pi)^2} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} e^{-i\underset{\sim}{k} \cdot \underset{\sim}{r}} \frac{1}{\left(a^2 + r^2\right)^{3/2}} dx\, dy ,$$

$$F\left(k_x, k_y\right) = F(k) = \frac{A}{(2\pi)k^{1/2}} \int_{o}^{\infty} \frac{r^{1/2}}{\left(a^2 + r^2\right)^{3/2}} J_o(kr)(kr)^{1/2} dr , \qquad (A.96)$$

where

$$k = \left(k_x^2 + k_y^2\right)^{1/2} .$$

The integral in Eq. (A.96) is recognized (Ref. A.3) as the Hankel transform of $r^{1/2}(r^2 + a^2)^{-3/2}$, so that F(k) becomes

$$F(k) = \frac{A}{2\pi a} e^{-ak} . \qquad (A.97)$$

If u_o is the unperturbed velocity, it follows that the first-order correction to the vertical component of the wind is given by

$$\bar{w}(x,y,z) = u_o \iint \left(ik_x\right) F(k)\, e^{i\left(k_x x + k_y y\right)}\, e^{-kz}\, dk_x\, dk_y \ ,$$

$$\bar{w}(x,y,z) = \frac{u_o A}{a} \frac{\partial}{\partial x} \int_o^{\infty} e^{-(a+z)k} J_o(kr)\, kdk \ ,$$

$$\bar{w}(x,y,z) = \frac{-3\lambda A u_o}{a} \frac{x}{\left(x^2 + y^2 + \lambda^2\right)^{5/2}} = \frac{-3\lambda a^2 h x u_o}{\left(r^2 + \lambda^2\right)^{5/2}} \ , \qquad \text{(A.98)}$$

where

$$\lambda = (z + a) \ .$$

The changes in the x and y components of velocity are determined from Eqs. (A.50) and (A.51). Thus, we have:

$$\bar{u}(x,y,z) = -u_o \iint \frac{\left(ik_x\right)\left(ik_y\right)}{k} F(k)\, e^{i\left(k_x x + k_y y\right)}\, e^{-kz}\, dk_x\, dk_y$$

$$\bar{u}(x,y,z) = -u_o \frac{\partial}{\partial x^2} \int_o^{2\pi} \int_o^{\infty} F(k)\, e^{ikr\cos\phi}\, e^{-kz}\, dk\, d\phi \ ,$$

$$\bar{u}(x,y,z) = u_o\left(a^2 h\right) \frac{\left(y^2 + \lambda^2 - 2x^2\right)}{\left(r^2 + \lambda^2\right)^{5/2}} \ ; \qquad \text{(A.99)}$$

and

$$\bar{v}(x\ y, z) = -u_o \iint \frac{(ik_y)(ik_x)}{k} F(k)\, e^{i\left(k_x x + k_y y\right)}\, e^{-kz}\, dk_x\, dk_y ,$$

$$\bar{v}(x, y, z) = -u_o \frac{\partial^2}{\partial x\, \partial y} \int_o^{2\pi} \int_o^{\infty} F(k)\, e^{ikr\cos\phi}\, e^{-kz}\, dk\, d\phi .$$

$$\bar{v}(x, y, z) = -\frac{3u_o\left(a^2 h\right)xy}{\left(r^2 + \lambda^2\right)^{5/2}} . \qquad (A.100)$$

Wind Streamlines and Fallout Particle Streamlines in Two Dimensions

It is of interest to obtain analytic expressions and pictorial representations for the trajectories of fallout particles for the purpose of assessing the importance of the terrain effects. If u_p and w_p denote the horizontal and vertical components of the fallout particle velocity in a two-dimensional system, it is well known that these quantities are related to the wind velocity through the equations

$$u_p = u_o + \bar{u} , \qquad (A.101)$$

and

$$w_p = -V_F + \bar{w} , \qquad (A.102)$$

where V_F is the so-called fall velocity. Strictly speaking V_F is a function both of particle size and of altitude (Ref. A.4), but below 10,000 ft its variation with z can be neglected. Figure A.2 shows the average fall velocity, between 0 and 10,000 ft, plotted as a function of particle size for spherical particles with an assumed density of 2.5 g cm^{-3}.

The flow lines, or trajectories, of fallout particles can be determined from a quantity called the stream function,[A.5] $\Phi(x, z)$, defined by the partial differential equations

$$w_p = -V_F + \bar{w} = -\frac{\partial \Phi}{\partial x}(x, z) , \qquad (A.103)$$

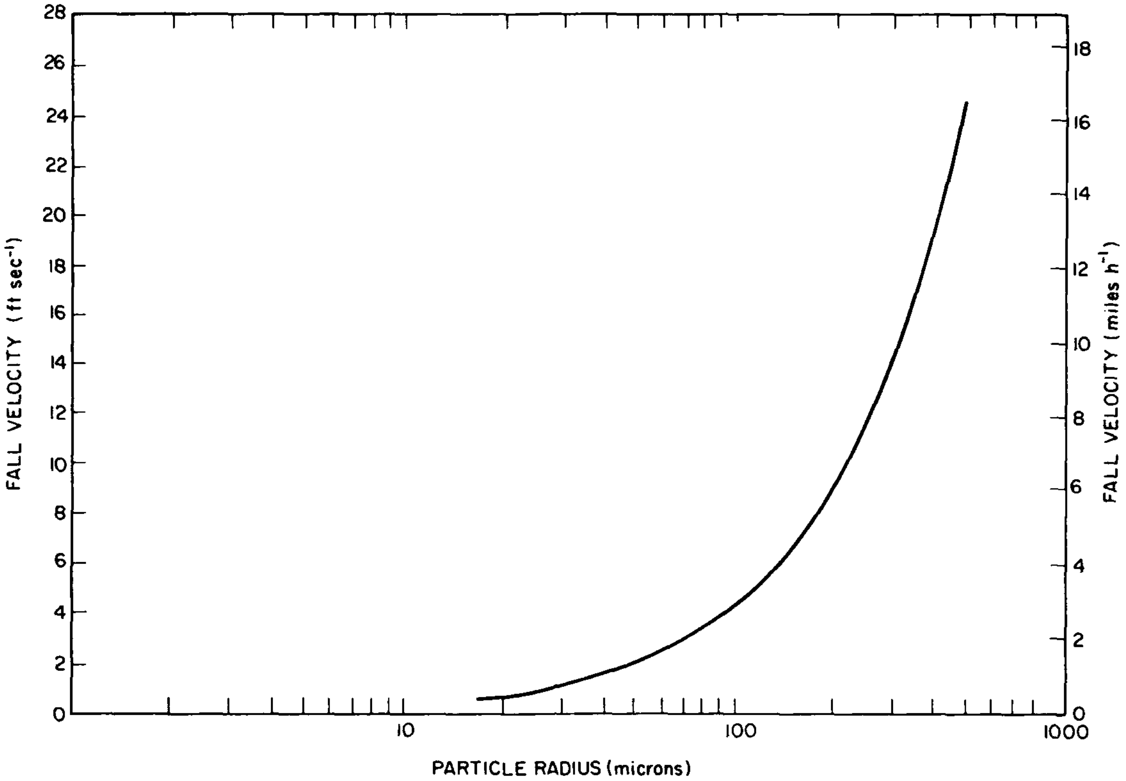


Figure A.2. Fall Velocity vs Particle Size

and

$$u_p = u_o + \bar{u} \equiv \frac{\partial \Phi}{\partial z}(x, z) \quad . \tag{A.104}$$

On the other hand, the equation for the flow lines is

$$\frac{dx}{u_p} = \frac{dz}{w_p} \quad \text{or} \quad -w_p dx + u_p dz = 0 \quad , \tag{A.105}$$

which when used with Eqs. (A.103) and (A.104) gives

$$\frac{\partial \Phi}{\partial x} dx + \frac{\partial \Phi}{\partial z} dz = 0 \quad \text{or} \quad d\Phi = 0 \quad . \tag{A.106}$$

We thus see that the curves for which

$$\Phi = \text{constant} \qquad \text{(A.107)}$$

are the streamlines. In the case of a mountain ridge perpendicular to the unperturbed flow it is easy to show that $\bar{u}$ and $\bar{w}$ are given by

$$\bar{u} = \frac{\partial \Psi}{\partial z} \ , \qquad \text{(A.108)}$$

and

$$\bar{w} = -\frac{\partial \Psi}{\partial x} \ , \qquad \text{(A.109)}$$

where the perturbed wind stream function $\Psi(x, z)$ is

$$\Psi = \frac{-u_o(ah)(z + a)}{(z + a)^2 + x^2} \ . \qquad \text{(A.110)}$$

Using Eqs. (A.108) and (A.109), and recalling that u_o and V_F are both independent of position, enables us to construct the entire stream function, $\Phi(x, z)$. The function $\Phi(x, z)$, which has as its partial derivates w_p and u_p, is

$$\Phi = u_o z + \Psi + V_F x \ . \qquad \text{(A.111)}$$

For computational purposes it is desirable to cast Eq. (A.111) in dimensionless form by dividing both sides by $(u_o a)$. The streamlines are then given by the equation

$$\text{constant} = C = \bar{z} + r\bar{x} - \alpha \frac{(1 + \bar{z})}{(1 + \bar{z})^2 + \bar{x}^2} \ , \qquad \text{(A.112)}$$

where

$\alpha = h/a$ = ratio of height to half width of mountain ridge,

$r = V_F/u_o$ = ratio of the magnitude of fall velocity to the unperturbed wind velocity, u_o,

$\bar{x} = (x/a)$ = horizontal dimension in units of a,

$\bar{z} = (z/a)$ = vertical position in units of a.

In the absence of a mountain ridge, $\alpha = 0$ and Eq. (A.112) reduces to

$$\bar{z} = C' - r\bar{x} \quad , \qquad (A.113)$$

which is the equation of the straight-line descent of a fallout particle with slope $-V_F/u_o$. On the other hand, the streamlines deduced from Eq. (A.112) when $r = 0$ depict the flow of the wind field over the mountain ridge. The solid lines in Figures A.3, A.4, and A.5 show the wind streamlines at various initial altitudes for values of $\alpha = 0.25$, 0.50, and 0.75. The dashed line on each figure is the mountain ridge function

$$\left(\frac{z}{a}\right) = \left(\frac{h}{a}\right) \frac{1}{1 + (x/a)^2} = \frac{\alpha}{1 + (x/a)^2} \quad .$$

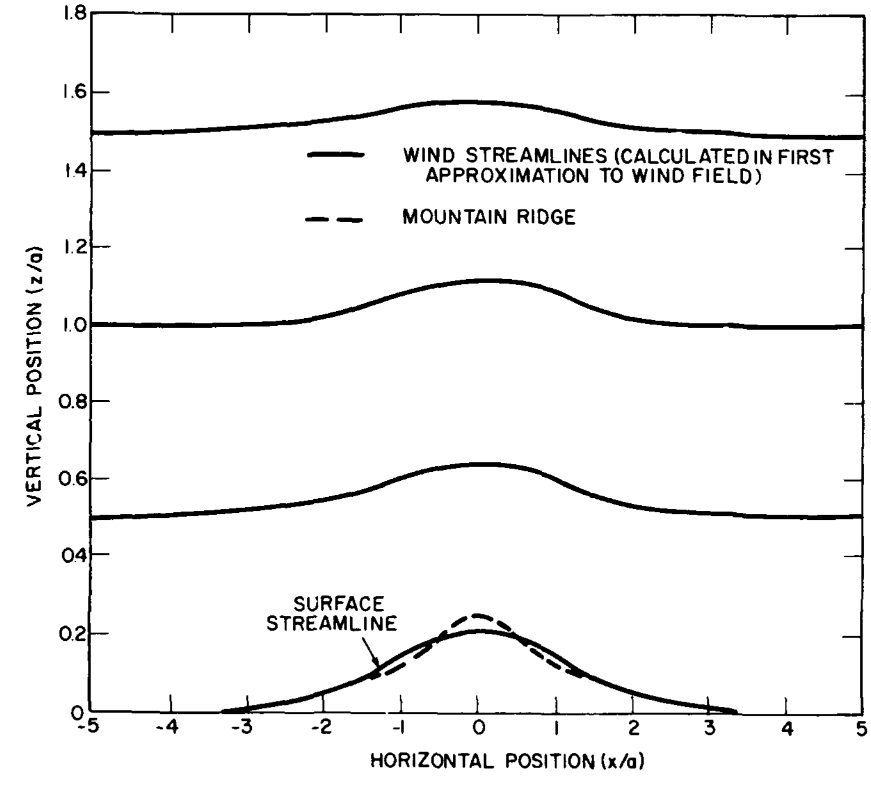


Figure A.3. Wind Streamlines for $\alpha = 0.25$ (Note vertical scale is amplified 10 times.)

Figure A.4. Wind Streamlines for $\alpha = 0.50$ (Note vertical scale is amplified 10 times.)

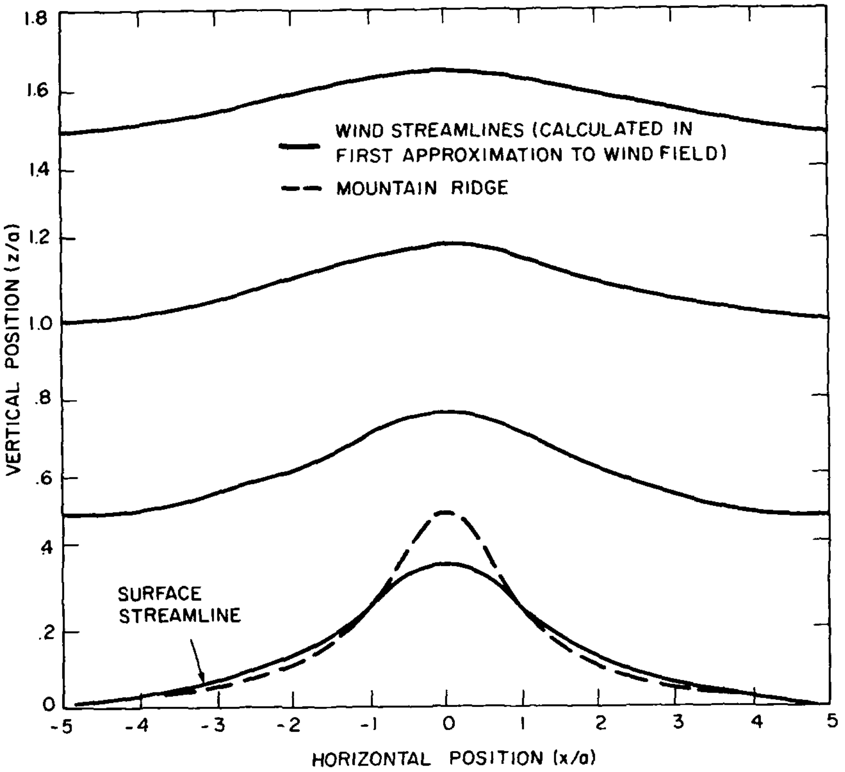
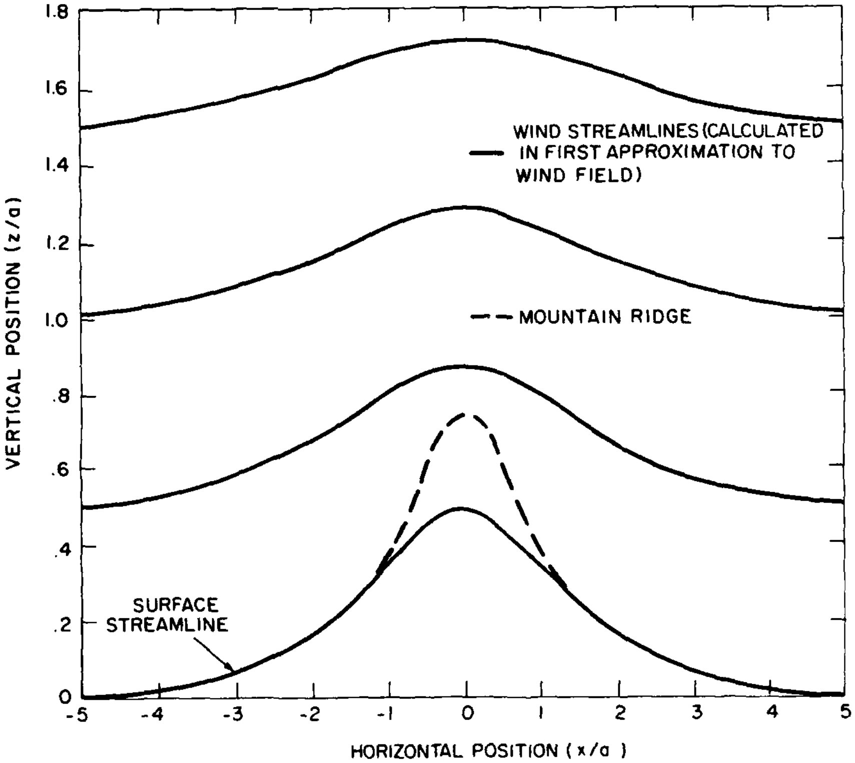


Figure A.5. Wind Streamlines for $\alpha = 0.75$ (Note vertical scale is amplified 10 times.)



We can readily observe in all cases that the higher altitude streamlines are less affected by the mountains than the lower ones. This is to be expected. It is also interesting to note that the wind flow corresponding to the surface streamline actually hits the mountain ridge in all cases. This is not unexpected in view of the approximate nature of the first-order calculation of the Fourier transform of the vertical component, C(k), of the wind. It will be recalled that the perturbed boundary conditions were applied exactly (in which we required that the wind velocity be parallel to the earth's surface). However, in the process of determining the wind field, an iteration scheme was developed to compute C(k), and the results shown in this section correspond to the first approximation

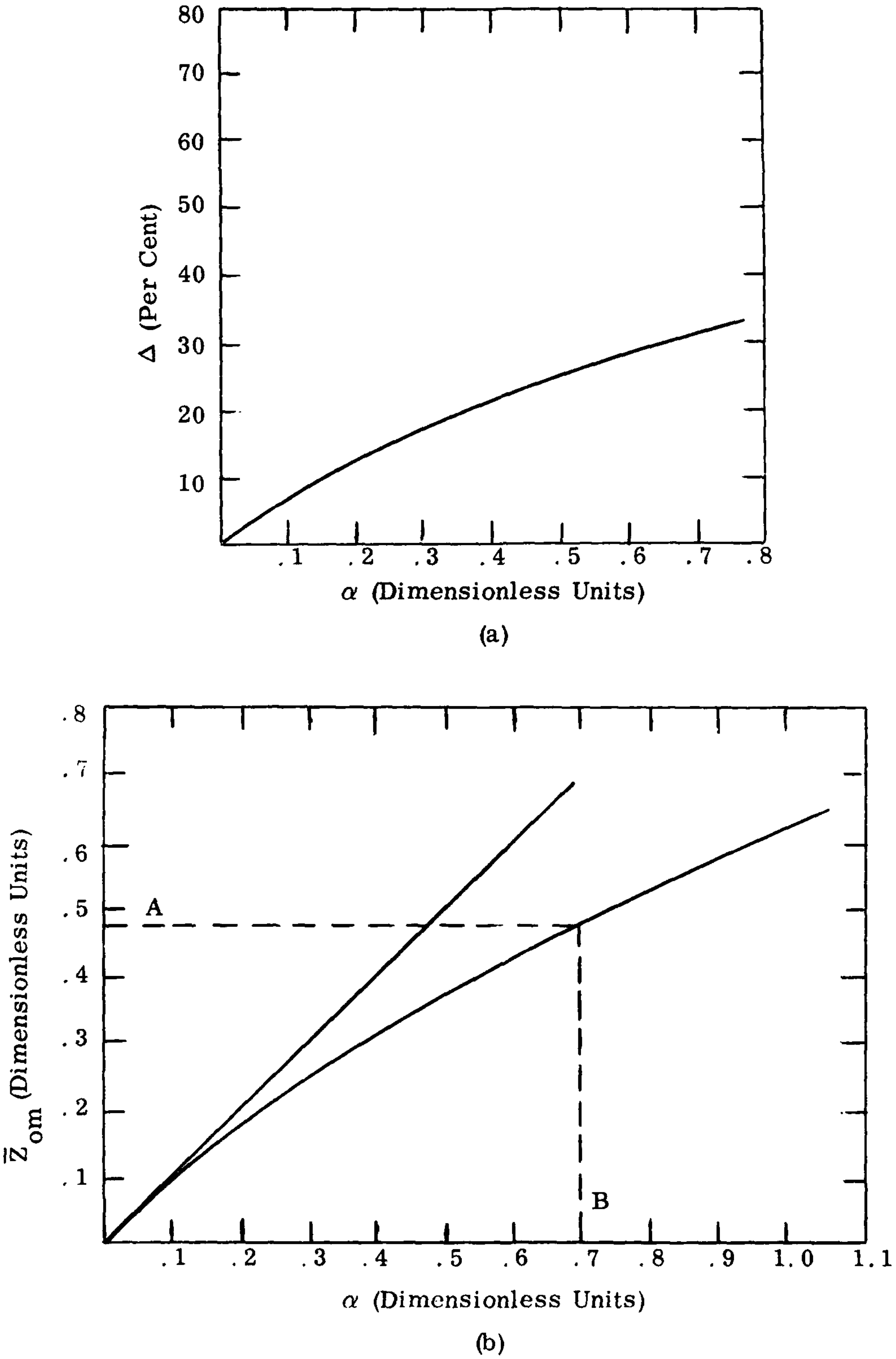
$$C^{(1)}(k) = \frac{u_o(ah)}{2} (ik)\, e^{-|k|a} \quad .$$

The uncertainties in the calculation (as noted earlier) should increase in proportion to the slope, which in the case of a mountain ridge is typified by the ratio (h/a). This is especially well borne out by the results which show that the relative difference, Δ, between the height of the mountain ridge and the maximum elevation increases with a corresponding increase in (h/a). We define Δ by the equation

$$\Delta = \frac{(h/a) - \bar{Z}_{om}}{(h/a)} \times 100 = \frac{\alpha - \bar{Z}_{om}}{\alpha} \times 100 \quad , \qquad (A.114)$$

where $\bar{Z}_{om}$ is the maximum elevation of the surface trajectory in units of a. Figure A.6(a) shows a plot of Δ vs (h/a) = α. As observed, the relative difference of trajectories increases as (h/a) the average slope of the mountain ridge increases, thereby reflecting the uncertainties in the calculation attributable to the first-order approximation.

The results also show that the first approximation to the wind field underestimates the airlift due to the mountain ridge. This is perhaps better illustrated by a comparison of $\bar{Z}_{om}$ vs α (see Figure A.6(b)), which like Figure A.6(a) shows that the discrepancies between the actual maximum "lift" and the ideal lift increase with α. (Mathematically, this discrepancy is the difference between the 45^o ideal



(a)

(b)

Figure A.6. Differences Between Surface Trajectory and Mountain Ridge

lift line and the actual curve of $\bar{Z}_{om}$ vs α.) Figure A.6(b) illustrates the necessity of executing the iteration scheme for C(k) in order to ensure the proper evaluation of the wind field. Since this may be a complicated process, however, we can use the results of Figure A.6(b) to establish an empirical relationship between calculated trajectories and the true mountain profile. Thus, suppose we have a mountain ridge whose maximum elevation, also measured in units of its half width, is 0.48 (point A in Figure A.6(b)). The curve shows that to ensure that the calculated surface trajectory would actually rise to a maximum elevation of 0.48, it is necessary to perform the calculations for an α equal to 0.7 (point B in Figure A.6(b)).

The curves of the fallout particle trajectories shown in Figures A.7, A.8, and A.9 depict a mountain ridge corresponding to the maximum elevation $\bar{Z}_{om}$, although as in the case for the wind streamlines, the calculations were performed for the corresponding values of α. Since it is beyond the scope of this report to perform a parametric analysis of the stream function, we present the results for a fall-to-wind velocity ratio, V_F/u_o, equal to 0.1; the curves differ only in the choice of α,

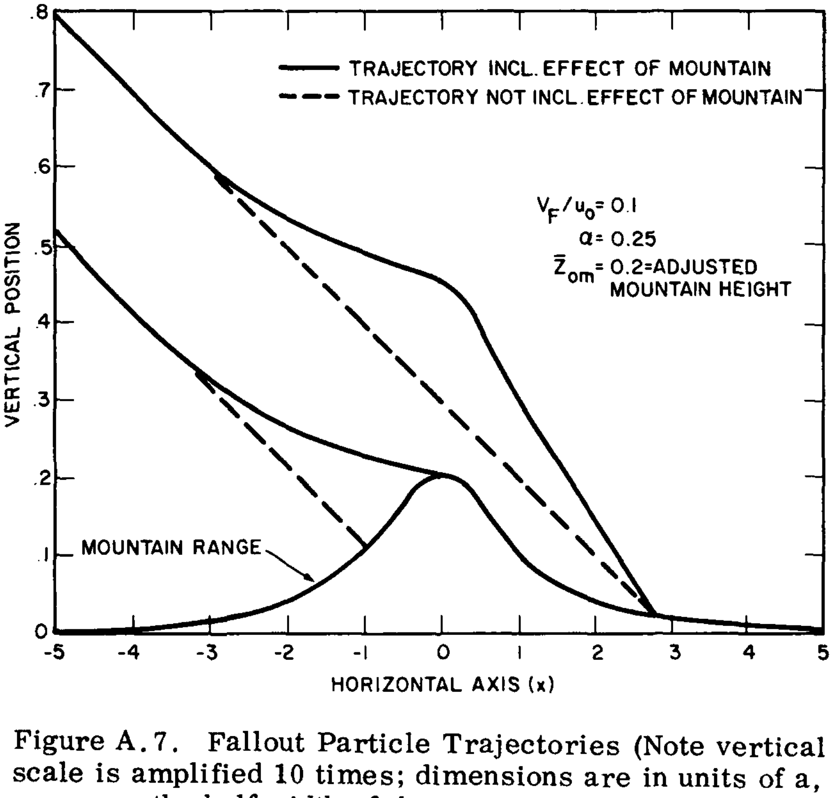


Figure A.7. Fallout Particle Trajectories (Note vertical scale is amplified 10 times; dimensions are in units of a, the half width of the mountain range.)

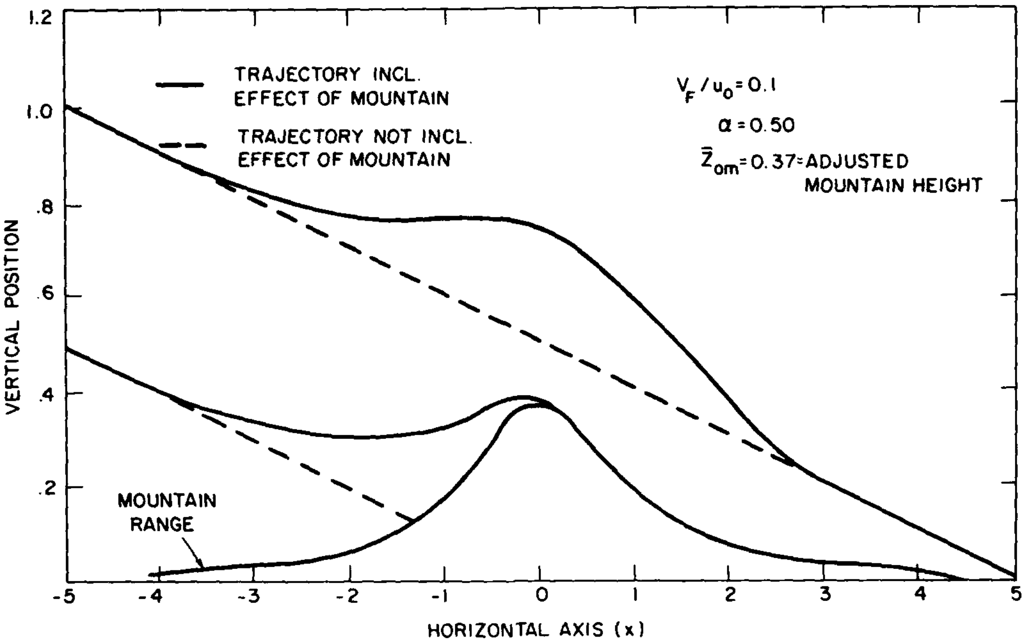


Figure A.8. Fallout Particle Trajectories (Note vertical scale is amplified 5 times; dimensions are in units of a, the half width of the mountain range.)

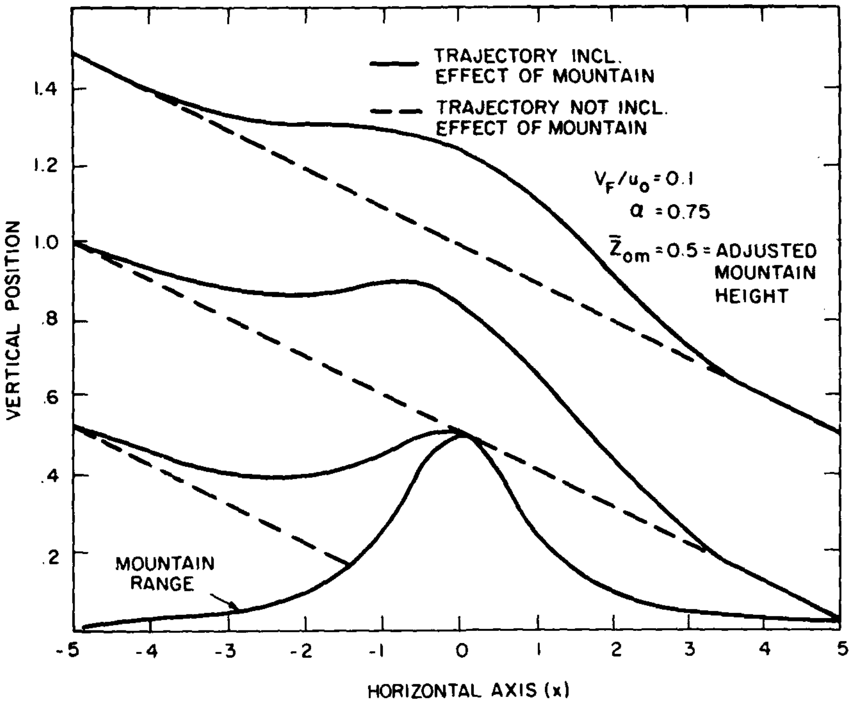


Figure A.9. Fallout Particle Trajectories (Note vertical scale amplified 5 times; dimensions are in units of a, the half width of the mountain range.)

or equivalently, $\bar{Z}_{om}$. All the curves originate at the dimensionless horizontal displacement, (x/a) = -5, sufficiently removed from the center of the mountain ridge so that terrain effects would not be felt. Examination of all three curves for the same initial vertical position of the streamlines shows that increases in the mountain ridge height lead to an enhanced downstream drift of the fallout particles. For those streamlines, whose unperturbed trajectories pass over the crest of the mountain ridge (e.g., the middle unperturbed trajectory of Figure A.9), the mountain ridge causes no permanent displacement of the streamlines. We have also constructed a digital program to compute the transport times for fallout particles traversing a two-dimensional mountain ridge for arbitrary γ and α and have applied the code for the cases $\gamma = 0.1$; $\alpha = 0.25$, 0.50, and 0.75 (between the limits $-5 \leq x \leq 5$). The results show no additional time delay due to the effect of the mountain ridge. On the contrary, we found a relative speedup of between 1 to 2%. Apparently, the increase in path length is slightly more than counterbalanced by the increase in velocity.

The fact that the perturbed trajectories which fail to intercept the mountain ridge always end up on the same unperturbed streamline is a general result, as can be seen by examination of the stream function,

$$C = \bar{z} + r\bar{x} - \left[\frac{\alpha(1 + \bar{z})}{(1 + \bar{z})^2 + \bar{x}^2}\right] .$$

The function in brackets is the contribution to the stream function attributable to the mountain ridge; for either large negative or positive values of $\bar{x}$ this goes to zero.

The middle set of curves in Figure A.9 can be used to obtain some estimate of the enhanced fallout range caused by the mountain ridge for $(V_F/u_o) = 0.1$ with $(\bar{Z}_{om}/a) = 0.5$. From Figure A.2 we see that this would correspond to a 100-μ particle with $u_o = 30$ mph, 150-μ particle with $u_o = 50$ mph, or a 230-μ particle with $u_o = 70$ mph, all of which are quite possible situations. If the actual mountain ridge peak were 1 mi, the intercept of the alluded-to trajectory would hit the horizontal axis at $\bar{x} = 5$ or x = 10 mi.

For heavy fallout particles, terrain effects are less important since the vertical lift decreases. At the other extreme, extremely light fallout particles will follow the wind streamlines.

Conditions for Neglecting the Coriolis Effect

We shall now examine the coefficients in the dispersion relationship — namely a, b, and c (see Eqs. (A.35) and (A.36)) — to determine the conditions on the velocity and wavelength for which the Coriolis effect can be neglected. Since we are primarily interested in short range effects, we shall freely make use of the assumed inequality

$$\left(k_x^2 + k_y^2\right)^{1/2} >> \beta = 0.75 \times 10^{-6} \text{ cm}^{-1} \quad , \qquad \text{(A.115)}$$

which signifies that the wavelength of the horizontal variations in the terrain is less than the $2\pi\beta^{-1}$, or approximately 50 mi.

The Coriolis effect can be neglected in Eq. (A.36a) if

$$|k_x| u_o >> \Omega \quad , \qquad \text{(A.116)}$$

or equivalently

$$(2\pi) \frac{|u_o|}{\Omega} >> L_x \quad , \qquad \text{(A.117)}$$

where L_x is a representative wavelength in the x direction. The distance (u_o/Ω) equals

$$\frac{u_o}{\Omega} = d = \left(3.8 \, u_m\right) \text{ mi} \quad , \qquad \text{(A.118)}$$

where u_m is the wind velocity expressed in miles per hour. This restricts L_x to less than 24 u_m mi. We have assumed the inequality of Eq. (A.117) to hold in our analysis. Equation (A.117) will not be satisfied when the unperturbed velocity is too large or when both a small u_o and large L_x are combined. However, these conditions are not important relevant to fallout considerations. If L_x is large, the disturbance cannot be considered as a local effect; hence, additional meteorological information will be available, thus precluding the utility of the perturbation methods considered here. On the other hand if u_o is small, the perturbed wind velocity will also be small (as is shown in the analysis) and terrain effects will not be important since the motion of the fallout particle will be essentially vertical.

Examination of Eqs. (A.36b) and (A.36c) shows that the second and third coefficients in the dispersion relationship, b and c, are already expanded in powers of Ω and thus are in a suitable form for examining the conditions under which the Coriolis effect may be neglected. (Neglecting the Coriolis effect is equivalent to omitting those terms which are proportional to Ω and Ω^2.) The ratio of the first-to-second terms in Eq. (A.36b) is

$$\frac{\gamma\beta k_x^2 u_o^2}{2\Omega|k_x||k_y|u_o\omega_x} = \frac{\gamma\beta L_y u_o}{4\Omega L_x \cos\Theta \sin\epsilon} , \qquad \text{(A.119)}$$

where L_y and L_x are characteristic wavelengths for the y and x dimensions respectively. Neglecting minor numerical factors, the condition that the foregoing relationship be greater than unity is approximately given by

$$0.5\left(L_y/L_x\right) u_m > 1 . \qquad \text{(A.120)}$$

For physically interesting wind velocities (e.g., $u_m > 10$ mph) the inequality of Eq. (A.120) will break down only in unusual cases. Although such occurrences can be treated by the general theory we also assume the inequality of Eq. (A.120).

Using Eq. (A.115) together with the assumption $k_x > k_y$ gives for the ratio of the first-to-third terms in the expression for b (again neglecting minor numerical factors)

$$\left(k_x^2 u_o^2/\Omega^2\right)\frac{\beta}{|k_x|} = r_1 . \qquad \text{(A.121)}$$

Using Eq. (A.118) we find that the requirement that the foregoing expression is much greater than unity is given by

$$2\pi(1.8)\, u_m^2 >> L_x \text{ (miles)} \;. \qquad \text{(A.122)}$$

The cases for which $L_x > 2\pi(1.8)\, u_m^2$ are not relevant to local fallout. If we now use Eq. (A.115) but assume $k_y > k_x$, we have in lieu of Eq. (A.119)

$$\frac{k_x^2 u_o^2}{\Omega^2} \frac{\beta}{|k_y|} = r_1\left(L_y/L_x\right) = \left[4\pi(1.8)\, u_m\right]\left(0.5\, L_y/L_x\right) u_m \;. \qquad \text{(A.123)}$$

Since $(0.5\, L_y u_m/L_x)$ is assumed greater than unity, the foregoing expression will also be greater than unity.

Recalling that $\sigma = (\sigma/\beta) = 1.2 \times 10^9 \text{ cm}^2 \text{ sec}^{-2} >> u_o^2$, and neglecting minor numerical factors, gives the following approximate expression for c:

$$c \simeq k_x^2 u_o^2 \sigma\left(k_x^2 + k_y^2\right) + \Omega\beta\sigma u_o k_x^2 + \Omega^2 \sigma k_x^2 \;. \qquad \text{(A.124)}$$

By using the previously mentioned inequalities it is easy to show that Ω and Ω^2 can be neglected in the expression for c.

Conclusions

A perturbation type model has been developed to compute the airflow over variable terrain. The theory is based on the assumption of the existence of an unperturbed state characterized by an adiabatic atmosphere and a uniform velocity, u_o, which would otherwise exist in the absence of ground variations. When the general theory is addressed to small scale disturbances, which are of interest in local fallout applications, there are no lee waves and we can neglect the Coriolis force. In this regime the theory has been applied to compute the wind field over a mountain (valley) and a mountain (valley) ridge. Using the calculated wind streamline for a mountain ridge it becomes possible to assess the importance of variable terrain on the motion of particles typical of those encountered in the nuclear fallout regime.

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APPENDIX B

THE INCORPORATION OF THE SEA BREEZE IN THE CALCULATION OF FALLOUT

Introduction

The effects of the sea breeze will be considered in our calculations of fallout. It is appreciated that this local circulation phenomenon can have an important effect on the lighter fallout particles, particularly on a clear day, when the temperature-induced circulating winds are larger than the so-called fall velocity, V_F.

The sea breeze is characterized by relatively large changes in the wind direction over short distances, and, as such, its internal features cannot be satisfactorily analyzed with existing installations because of the unavailability of sufficiently dense meteorological observation points in the vicinity of the coastline. We have developed, therefore, a suitable sea breeze model which can be applied in a digital computer program leading to the determination of fallout distribution. As in the overall DOD fallout model, space is divided into cells, with each compartment characterized by a distinct wind field. In the general case, the wind parameters for these cells are deduced (by suitable mathematical techniques) from sounding stations which are in close proximity to the geometric center of the cell. The construction of the cell's wind field by this method is appropriate throughout most of space where changes in the wind velocity occur over dimensions which are large compared to the distance between observation points. The sea breeze and other local circulation systems such as mountain and valley winds, however, cannot be treated by this method. Consequently, the geometric region enclosing the sea breeze is divided into a special cell which is treated separately. The nature of the problem dictates that analytic mathematical functions be used to generate the wind field in this cell. These functions, moreover, should be applicable for most situations.

Review of the Sea-Breeze Theories

The sea breeze is perhaps one of the best examples of an atmospheric process which can be treated analytically with a degree of success. Jeffreys[B.1] was the first to treat the problem in an exact way, although his results were not in full agreement with observations. As pointed out by Schmidt,[B. 2] the former' s model led to a solution in which the daily wind variation was in phase with the daily temperature curve. This was not always consistent with the measured results. In the Jeffreys model, the only forces that are taken into account are the two due to friction and to the pressure gradient resulting from the unequal heating. Haurwitz[B. 3] classifies such a model as an equilibrium theory of the sea breeze — a theory which neglects the inertia of the wind and, consequently, the temporal changes of the wind that are of the order of $\Omega = 2\pi/(\text{sidereal day}) = 7.3 \times 10^{-5}$ sec. In retrospect, the main flaw in Jeffreys treatment was not so much his neglect of the inertia of the wind (as will be shown later, this can be justified in some cases) but rather his deletion of the Coriolis terms which account for the veering of the wind in the course of time. This effect was included in the subsequent papers.

The works of both Schmidt and Haurwitz were less concerned with rendering complete theory of the sea breeze than with clarifying the characteristic phenomena of the land and sea breezes, such as the phase shift between wind and temperature or the influence of the earth's rotation. These investigations did much to improve our understanding of the sea breeze, but they cannot be considered as complete in the usual sense. (A more thorough critique of their work is given by Defant,[B. 4] who also discusses research performed by other investigators.)

In analytical treatments of the sea breeze, it is necessary to make simplifying assumptions in order to obtain mathematically tractable equations. We can categorically say that all the analytical treatments are based upon linearization of the equations of motion which describe the sea-breeze circulation. The more complete analytical treatments of the sea breeze have been successful in accounting for the large scale characteristics of the sea-breeze circulation. Notable among this group are the investigations of Defant[B. 4, B. 5] and Haurwitz,[B. 6] which form the basis of the sea-breeze model used in our fallout computation. (A discussion of their work is given in the following section of this appendix.) Generally, the terms in the dynamical equations which deal with the horizontal advection of temperature are omitted, although in the Defant-Haurwitz models, vertical advection of temperature is retained, and the diffusion of heat upward by turbulent processes is included. Despite the approximations resulting from linearization, the linear models do yield a satisfactory reproduction of the fundamental field of motion of the sea breeze.

The development of high speed numerical methods has made possible a more refined treatment of the sea breeze which can account for not only horizontal advection but also the spatial variation of the viscosity and turbulent diffusion constants. Pierce[B.7] was perhaps the first who succeeded in integrating by numerical methods a set of nonlinear sea breeze equations. The main drawback in Pierce's model was his introduction of a somewhat artificial mechanism to transfer the heat absorbed by the earth to the atmosphere. The physical consequences of this are more fully discussed by Fisher.[B.8] As pointed out by Fisher, the most important feature of the numerical method lies in the fact that the nonlinear advective terms in the equations may be retained and thus allow the feedback effect of the wind field itself on the sea breeze to be studied. Fisher's model is conceptually identical to the linear model of Haurwitz and may be considered the most definitive work in the field inasmuch as it includes not only nonlinear horizontal advection but also the spatial variation of the transport parameters. This solution shows the sea breeze in the stages of development and decay and succeeds in reproducing the gross features of the wind system and many of its small details as well.

The main drawback in applying Fisher's model to the fallout problem is its sheer complexity, particularly in view of the fact that, as pointed out by Fisher himself, its principal contribution is its ability to describe the fine structure in the sea-breeze development. Although we can justify the incorporation of the sea breeze in fallout models, we are hard-pressed to justify the inclusion of its subleties. Other effects such as the irregularity of the coastline, the presence of a prevailing wind, and uncertainties in the transport coefficients would completely overshadow any improvement attributed to incorporation of the sea-breeze fine structure. (Recently, an attempt was made by Travelers Insurance Research Laboratory[B.9] to employ Fisher's observed data for calculation of fallout in a sea breeze In view of the extensive amount of "function-fitting" employed, it becomes difficult to appraise their model.)

Sea-Breeze Model

Wind-Field Parameters

In this section, we shall present the expressions for the components of the wind field that are used in our sea breeze calculations and are identical to those deduced by Defant.[B.5] The derivation of our final results, however, closely resembles Haurwitz's treatment of the sea-breeze circulation because it shows more clearly the assumptions which are made concerning the pressure variation.

Defant's approach to the sea-breeze problem is based on Lord Rayleigh's convection theory.[B.10] The dynamics of Defant's model are governed by the continuity equation, the three equations of motion, the equation of state, and the heat-diffusion equation. By neglecting variations in density except in so far as they modify the action of gravity, it becomes possible to construct a stream function which is used to describe the motion in the plane perpendicular to the coast. The mathematical equations are based on the assumption of an infinitely long coastline which we designate as the y axis. Variations of the meteorological equations in this direction are ignored. The x axis is perpendicular to the coast, and positive inland, while the z axis denotes the vertical. The equations which describe the system are:

$$\frac{\partial u}{\partial x} + \frac{\partial w}{\partial z} = 0 \quad , \tag{B.1}$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + w\frac{\partial u}{\partial z} - fv = -\frac{1}{\rho}\frac{\partial p}{\partial x} - \sigma u \quad , \tag{B.2}$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + w\frac{\partial v}{\partial z} + fu = -\sigma v \quad , \tag{B.3}$$

$$\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + w\frac{\partial w}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial z} - g - \sigma w \quad . \tag{B.4}$$

$$p = \rho RT \quad . \tag{B.5}$$

and

$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + w\frac{\partial T}{\partial z} = K\frac{\partial^2 T}{\partial z^2} \quad , \tag{B.6}$$

where u, v, and w are the velocity components along the x, y, and z axes, respectively; p denotes the pressure; T is the temperature; ρ is the mass density; g is the gravitational constant; K is the thermal diffusion constant; and R is the gas constant. The quantity $f = 2\Omega \sin \phi$ is the Coriolis parameter, while the effect of friction is taken in account through the Guldberg-Mohn friction parameter, σ. To be sure, this is the simplest way to incorporate the effect of viscosity into the theory. (Haurwitz offers an alternative approach to turbulent dissipation but, as we shall discuss later, this has its own drawbacks.) With the exception of Eq. (B. 1) (the continuity equation derived by setting $(d\rho/dt) = 0$, see Ref. B. 8) all the others are nonlinear in the sense that there are terms which involve multiplication of the dependent meteorological variables Application of the following boundary conditions suffices to determine the problem in all cases:

$$\begin{aligned} &w(z = 0) = 0 \quad , \\ &w(z \rightarrow \infty) = 0 \quad , \qquad\qquad (B. 7) \\ &T(z = 0) = T_o + T(x, t) \quad . \end{aligned}$$

The function T(x, t) is the surface temperature differential, which is defined as the difference between the actual temperature above the water or land, and a suitable reference temperature, T_o, which we take to be the temperature along the coastline. In the theory of the sea breeze T(x, t) performs the role of the "driving-force" in that it, alone, is responsible for the circulation

Before proceeding with our discussion of the solution of the sea-breeze equations, it is appropriate to review a variation of the sea-breeze model as rendered by Haurwitz.[B. 6] The difference between Haurwitz's model and Defant's lies in the method of treating turbulent friction Instead of using the Guldberg-Mohn friction parameter, σ, to describe turbulent dissipation, Haurwitz employs kinematic viscosity. Thus, in lieu of the terms, $-\sigma u$ and $-\sigma v$, which appear in our Eqs. (B. 2) and (B. 3), his corresponding friction terms are $K\partial^2 u/\partial z^2$ and $K\partial^2 v/\partial z^2$, where the kinematic viscosity K is assumed to be independent of position. Haurwitz also neglects the viscous effects on the vertical wind component; we do not. When viscosity is introduced by the expressions $K\partial^2 u/\partial z^2$ and $K\partial^2 v/\partial z^2$, which are then used with the boundary conditions $u(z=0)=v(z=0)=0$, we arrive at a sea-breeze model in which a boundary layer (in the sense of Schlicting and Prandtl) is built into the theory. In such a situation, the horizontal components of velocity increase with altitude from a minimum value of zero at the land and water surface. According to Haurwitz's model, the distance over which this buildup occurs is of the order of the characteristic height of the sea breeze. This seems to be somewhat inconsistent with the everyday experiences at the ocean front where strong horizontal winds are evident a few feet from the ground. Strictly speaking, when boundary layer theory is used, the temperature of the moving fluid at the boundary is the same as the surface temperature Thus, if the theory of the boundary layer were rigorously applied on a clear sunny day in the summertime, we would necessarily have to use a land temperature of about 90° - 100°F and a water temperature between 60° - 70°F. This corresponds to a temperature differential of about 20°C, which would produce wind velocities greater than those measured. In addition, according to the usual boundary layer theory, this is also the surface air temperature differential. Again, this is inconsistent with observations. Haurwitz's treatment of friction thus seems to lead to inconsistencies, at least in the lower regions of the sea breeze. It is also more complicated since it introduces a much more cumbersome expression for the vertical attenuation constant. Consequently, the fundamental equations which describe our system are based on the Defant sea breeze model.

Equations (B. 1) - (B. 6) can be simplified by introducing two new variables, the stream function ψ and the vorticity η, which are related to the x and z component of the velocity by

$$u = -\frac{\partial\psi}{\partial z} , \quad w = \frac{\partial\psi}{\partial x} \qquad \text{(B. 8)}$$

$$\eta = \frac{\partial u}{\partial z} - \frac{\partial w}{\partial x} = \nabla^2 \psi \qquad \text{(B. 9)}$$

By operating on Eq. (B.2) with $(\partial/\partial z)$ and on Eq. (B.4) with $(\partial/\partial x)$, and then subtracting the resulting second expression from the resulting first expression, gives us the following equation for η:

$$\frac{\partial \eta}{\partial t} + \left(u \frac{\partial}{\partial x} + w \frac{\partial}{\partial z} \right) \eta - f \frac{\partial v}{\partial z} = - \frac{1}{\rho^2} \left(\frac{\partial \rho}{\partial z} \frac{\partial p}{\partial x} - \frac{\partial \rho}{\partial x} \frac{\partial p}{\partial z} \right) - \sigma \eta \quad . \tag{B.10}$$

The first term on the right-hand side is what Haurwitz calls the solenoid term, S, which can be simplified by use of the ideal gas law $p = \rho RT$.

$$S = - \frac{1}{\rho^2} \left(\frac{\partial \rho}{\partial z} \frac{\partial p}{\partial x} - \frac{\partial \rho}{\partial x} \frac{\partial p}{\partial z} \right) = \frac{R}{p} \left(\frac{\partial T}{\partial x} \frac{\partial p}{\partial z} - \frac{\partial T}{\partial z} \frac{\partial p}{\partial x} \right) \quad . \tag{B.11}$$

Since the first part of S is much larger than the second (see Ref. B.6), we have

$$S = \frac{R}{p} \left(\frac{\partial T}{\partial x} \frac{\partial p}{\partial z} \right) = - \frac{g}{T} \left(\frac{\partial T}{\partial x} \right) \quad . \tag{B.12}$$

As is usual in dynamic meteorology, we now replace $(1/T)\ (\partial T/\partial x)$ in Eq. (B.12) by $(1/\tilde{\theta})\ (\partial \tilde{\theta}/\partial x)$, where $\tilde{\theta}$ is the so-called potential temperature. In Eq. (B.6) we replace T by $\tilde{\theta}$; thus,

$$\frac{\partial \tilde{\theta}}{\partial t} + u \frac{\partial \tilde{\theta}}{\partial x} + w \frac{\partial \tilde{\theta}}{\partial z} = \frac{\partial^2 \tilde{\theta}}{\partial z^2} \quad . \tag{B.13}$$

Note in Eqs. (B.6) and (B.13) that only the vertical heat conduction has been taken into account since the vertical temperature gradient is generally much larger than the horizontal gradient.

At this point, the system of equations is linearized. That is, the meteorological variables are assumed to consist of an unperturbed part, that contribution which exists in the absence of the temperature differential T(x, t); and a smaller perturbed part, attributed to the driving force. Since in the system we consider, all the initial velocities equal to zero, u, v, and w are themselves the perturbed velocities. For the potential temperature we write

$$\tilde{\theta} = \theta_o(z) + \theta(x, z, t) \quad , \qquad \text{(B. 14)}$$

where θ_o and θ are the perturbed and unperturbed parts, respectively. We then arrive at a set of linearized equations:

$$-\frac{\partial}{\partial t}\left(\nabla^2 \psi\right) - f\frac{\partial v}{\partial z} = -\frac{g}{\theta_o}\frac{\partial \theta}{\partial x} + \sigma\nabla^2 \psi \ , \qquad \text{(B. 15)}$$

$$\frac{\partial v}{\partial t} - f\frac{\partial \psi}{\partial z} = -\sigma v \quad , \qquad \text{(B. 16)}$$

and

$$\frac{\partial \theta}{\partial t} + \Gamma\frac{\partial \psi}{\partial x} = K\frac{\partial^2 \theta}{\partial z^2} \quad , \qquad \text{(B. 17)}$$

where

$$\Gamma = \frac{\partial \theta_o}{\partial z} \quad .$$

Specifically, the convection terms such as $u(\partial u/\partial x)$, $u(\partial w/\partial x)$, and $w(\partial u/\partial z)$ have been neglected in the derivation of Eqs. (B. 15) - (B. 17). The justification for this can be examined by a comparison of their importance with the corresponding friction term. For example, let us compare the anticipated numerical value of the convection operator $D_u = u(\partial/\partial x) + w(\partial/\partial z)$ with σ, the Guldberg-Mohn parameter in Eq. (B. 2). Roughly speaking, D_u can be assigned a value approximately equal to:

$$D_u \approx \frac{\bar{u}}{L_x} + \frac{\bar{w}}{L_z} \quad , \qquad \text{(B. 18)}$$

where $\bar{u}$ and $\bar{w}$ are suitable average values of the respective velocity components, and L_x and L_z are characteristic dimensions of the horizontal and vertical extent of the sea breeze. L_x is a given quantity in that it is known a priori, while L_z is determined from the theory. The landward range of the sea breeze is estimated by many observers to lie between 15 - 50 km in the temperate zones, while in the tropical regions it can extendfrom 50 - 65 km and even as high as 124 - 145 km in the interior.[B.4] Representative values for different locations are included in Table B. 1. The vertical extent of the sea breeze, L_z, varies with location, but it is substantially smaller than the horizontal dimension. Its altitude varies from 150 m over medium-sized lakes to 200 - 500 m over large lakes and the coastal regions and rises to more than 1000 m in warm climates. It is also a characteristic feature of the sea breeze that the horizontal velocity greatly exceeds the vertical component. Under a set of conditions which gave results consistent with observation, Defant found an average horizontal velocity component of $\bar{u} = 2$ m sec^{-1} for every centigrade degree of temperature difference as opposed to a corresponding value of $\bar{w} = 2$ cm sec^{-1} $^{\circ}\mathrm{C}^{-1}$. If these results are used in Eq (B. 18) with $L_x = 20$ km, $L_z = 500$ m, and a maximum temperature differential of $5^{\circ}\mathrm{C}$ is assumed, we obtain the following value of D_u

TABLE B. 1

TYPICAL SEA BREEZE VALUES

Range (km)	Location
16-32	New England
15	Flemish Coast
20-30	Baltic Sea
30-40	Holland
40-50	Sweden
up to 50	Jutland
40	Albania
>50	Northern Coast of Java

$$D_u \approx \frac{10}{20 \times 10^3} + \frac{0.1}{500} \approx 7 \times 10^{-4} \ \mathrm{sec}^{-1} \qquad \text{(B. 19)}$$

Unfortunately, this is greater than a realistically high value of $\sigma = 2.5 \times 10^{-4}$, so that we cannot unequivocally disregard the nonlinear terms based upon the rough estimate of D_u. It is possible that phase differences between the constituents of the operator $D_u(u, \partial/\partial x, w, \partial/\partial z)$ can lead to cancellations, thereby precluding the use of a meaningful average. Despite this seeming contradiction, the remarkable feature of Defant's model is that it works. Apparently, the nonlinear terms do not significantly alter the main features of the sea breeze.

Within the altitude range for which the sea breeze is important, the potential temperature θ_o can be considered constant in Eq. (B.15), and its derivative at equilibrium, Γ, a constant in Eq. (B.17). This procedure renders Eqs. (B.15) - (B.17) linear with constant coefficients, and thus amenable to a solution by separation of variables.

The solution of Eqs. (B.15) - (B.17) is achieved by first assuming that x variation of the variables is given by

$$\theta = A(z,t)\sin\lambda x \qquad \text{(B.20)}$$

$$\psi = B(z,t)\cos\lambda x \quad \begin{cases} u = -(\partial\psi/\partial z) = -\cos\lambda x(\partial B/\partial z) \\ w = \partial\psi/\partial x = -\lambda\sin\lambda x B \end{cases} \qquad \text{(B.21)}$$

$$v = C(z,t)\cos\lambda x , \qquad \text{(B.22)}$$

Since the surface temperature differential can in general be represented by a Fourier series in multiples of the sidereal day frequency Ω, it follows from the principle of linear superposition that A, B, and C will be given by

$$A(z,t) = \sum_{n=1}^{\infty} A_n(z)\, e^{in\Omega t} , \qquad \text{(B.23)}$$

$$B(z,t) = \sum_{n=1}^{\infty} B_n(z)\, e^{in\Omega t} , \qquad \text{(B.24)}$$

and

$$C(z,t) = \sum_{n=1}^{\infty} C_n(z)\, e^{in\Omega t} . \qquad \text{(B.25)}$$

Combining Eqs. (B.20) - (B.25), inserting them into Eqs. (B.15) - (B.17), and equating equal powers of exp (in Ωt) gives the following coupled equations for A_n, B_n, and C_n:

$$(\sigma + in\Omega)\left(B_n'' - \lambda^2 B_n\right) + f\,C_n' = \alpha\lambda A_n \;, \tag{B.26}$$

and

$$(\sigma + in\Omega)\;C_n = f\,B_n' \;, \tag{B.27}$$

$$in\Omega\;A_n - \lambda\Gamma B_n = KA_n'' \;, \tag{B.28}$$

where

$$\alpha = g/\theta_o \;.$$

For computational purposes it is more convenient to deal with functions $W_n(z)$ defined by the equation

$$W_n = -\lambda B_n \;, \tag{B.29}$$

in terms of which the velocity components are given by

$$w(x,z,t) = \sin\lambda x \sum_{n=1}^{\infty} W_n(z)\,e^{in\Omega t} \;, \tag{B.30}$$

$$u(x,z,t) = \lambda^{-1}\cos\lambda x \sum_{n=1}^{\infty} W_n'(z)\;e^{in\Omega t} \;, \tag{B.31}$$

and

$$v(x,z,t) = \sum_{n=1}^{\infty} \left(f/q_n\right)\,U_n(x,z)\;e^{in\Omega t} \;, \tag{B.32}$$

where

$$q_n = \sigma + in\Omega \;. \tag{B.33}$$

Eliminating Eq. (B. 27) and using (B. 29) gives

$$W''_n = a_n W_n - b_n A_n , \qquad (B.34)$$

and

$$A''_n = c_n W_n + d_n A_n , \qquad (B.35)$$

where

$$a_n = \frac{q_n^2 \lambda^2}{\left(q_n^2 + f^2\right)} , \quad c_n = \frac{\Gamma}{K} ,$$

$$(B.36)$$

$$b_n = \frac{q_n \alpha \lambda^2}{\left(q_n^2 + f^2\right)} , \quad d_n = \frac{in\Omega}{K} .$$

If we now let

$$A_n(z) = \hat{A}_n e^{\alpha_n z} , \qquad (B.37a)$$

and

$$W_n(z) = \hat{W}_n e^{\alpha_n z} , \qquad (B.37b)$$

where $\hat{A}_n$ and $\hat{W}_n$ are the values at the surface, and substitute Eq. (B.37) into Eqs. (B.34) and (B.35), we derive the following matrix equation which must be satisfied in order to obtain a nontrivial solution:

$$\begin{pmatrix} b_n & \mu_n - a_n \\ \mu_n - d_n & -c_n \end{pmatrix} \begin{pmatrix} \hat{A}_n \\ \hat{W}_n \end{pmatrix} = 0 , \qquad (B.38)$$

where

$$\mu_n = \alpha_n^2 \quad . \qquad (B.39)$$

The only nontrivial solutions to Eq. (B.38) are those for which the determinant vanishes. This gives the two "allowed" values for μ_n:

$$\mu_{n1} = \frac{\left(a_n + d_n\right) + \quad \left(a_n + d_n\right)^2 - 4\left(a_n d_n + c_n b_n\right)^{1/2}}{2} = E_{n1}\, e^{i\gamma_{n1}} \ ,$$

$$\mu_{n2} = \frac{\left(a_n + d_n\right) - \quad \left(a_n + d_n\right)^2 - 4\left(a_n d_n + c_n b_n\right)^{1/2}}{2} = E_{n2}\, e^{i\gamma_{n2}} \ . \qquad \text{(B. 40)}$$

The roots of the dispersion relationship correspond to four values of α_n which are given by

$$\alpha_n = \pm\, E_{n1}^{1/2}\, e^{\left(i\gamma_{n1}/2\right)} = \pm\, U_{n1}\left[\cos\left(\eta_{n1}\right) + i \sin\left(\eta_{n1}\right)\right] \ , \qquad \text{(B. 41a)}$$

and

$$\alpha_n = \pm\, E_{n2}^{1/2}\, e^{\left(i\gamma_{n2}/2\right)} = \pm\, U_{n2}\left[\cos\left(\eta_{n2}\right) + i \sin\left(\eta_{n2}\right)\right] \ , \qquad \text{(B. 41b)}$$

where

$$\eta_{n1} = \gamma_{n1}/2, \ \eta_{n2} = \gamma_{n2}/2, \ U_{n1} = E_{n1}^{1/2} \ , \ U_{n2} = E_{n2}^{1/2} \ . \qquad \text{(B. 41c)}$$

Of the four possible roots for α_n only two are acceptable — one from Eq. (B.41a) and one from Eq. (B.41b). The criterion for selecting the roots is that the real parts of α_n must be negative so as to insure exponential damping of the sea breeze. We define the two roots for α_n by the equations

$$\alpha_{n1} = \epsilon_{n1}\mu_{n1}^{1/2} = \epsilon_{n1} U_{n1}\left[\cos\left(\eta_{n1}\right) + i \sin\left(\eta_{n1}\right)\right] = k_{n1} + i\ell_{n1} \ , \qquad \text{(B. 42a)}$$

and

$$a_{n2} = \epsilon_{n2}\mu_{n2}^{1/2} = \epsilon_{n2} U_{n2}\left[\cos\left(\eta_{n1}\right) + i \sin\left(\eta_{n1}\right)\right] = k_{n2} + i\ell_{n2} \ , \qquad \text{(B. 42b)}$$

where

$$\begin{aligned} \epsilon_{n1} &= +1 \text{ if } \cos\left(\eta_{n1}\right) < 0 \ , \\ \epsilon_{n1} &= -1 \text{ if } \cos\left(\eta_{n1}\right) > 0 \ , \\ \epsilon_{n2} &= +1 \text{ if } \cos\left(\eta_{n2}\right) < 0 \ , \\ \epsilon_{n2} &= -1 \text{ if } \cos\left(\eta_{n2}\right) > 0 \ . \end{aligned} \tag{B.43}$$

In terms of the α_n the solution to the problem is given by

$$\theta = \sin \lambda x \sum_{n=1}^{\infty} \left(\hat{A}_{n1}\, e^{\alpha_{n1} z} + \hat{A}_{n2}\, e^{\alpha_{n2} z} \right) e^{in\Omega t} \ , \tag{B.44}$$

$$w = \sin x \sum_{n=1}^{\infty} \left(r_{n1} \hat{A}_{n1}\, e^{\alpha_{n1} z} + r_{n2} \hat{A}_{n2} e^{\alpha_{n2} z} \right) e^{in\Omega t} \ , \tag{B.45}$$

$$u = \lambda^{-1} \cos \lambda x \sum_{n=1}^{\infty} \left(\alpha_{n1}\, r_{n1}\, \hat{A}_{n1}\, e^{\alpha_{n1} z} + \alpha_{n2}\, r_{n2}\, \hat{A}_{n2}\, e^{\alpha_{n2} z} \right) e^{in\Omega t} \ , \tag{B.46}$$

$$v = \lambda^{-1} \cos \lambda z \sum_{n=1}^{\infty} g_n \left(\alpha_{n1}\, r_{n1}\, \hat{A}_{n1}\, e^{\alpha_{n1} z} + \alpha_{n2} r_{n2} \hat{A}_{n2} e^{\alpha_{n2} z} \right) e^{in\Omega t} . \tag{B.47}$$

where

$$g_n = -\left(f/q_n\right) \quad , \tag{B.48}$$

and

$$r_{n1} = -b_n/\left(\mu_{n1} - a_n\right), \; r_{n2} = -b_n/\left(\mu_{n2} - a_n\right) \quad . \tag{B.49}$$

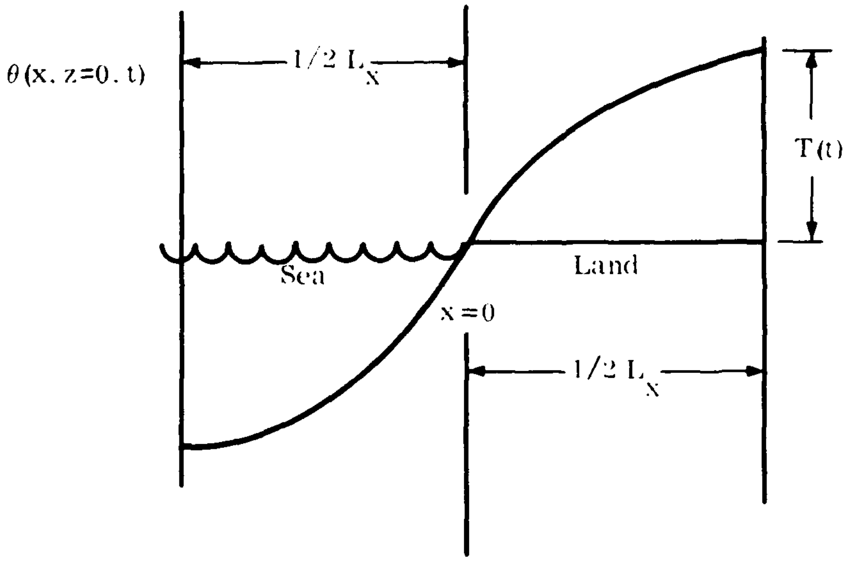
Up to this point the analysis has been carried out in complex arithmetic. The actual physical meteorological quantities are obtained by first determining $\hat{A}_{n1}$ and $\hat{A}_{n2}$ from the boundary conditions, and then taking the real parts of Eqs. (B. 44) - (B. 47).

Boundary Conditions

In the theoryofthe sea breeze it is assumed that the shape of the temperature differential at the surface is given by

$$\theta(x, z=0, t) = \sin \lambda x \; T(t) \quad ,$$

where T(t) is a function of time. A positive value of T(t) corresponds to the surface temperature profile shown in Figure B. 1, in which the land temperature



Figrro R. 1. Surface Temperature Variation is higher than the temperature over the water. T(t) is expressible as a Fourier series in multiples of the sidereal day frequency, Ω,

$$T(t) = \sum_{n=1}^{\infty} T_n e^{in\Omega t} \quad , \qquad (B.50)$$

where

$$T_n = \Omega(2\pi)^{-1} \int_0^{(2\pi/\Omega)} T(t)\, e^{-in\Omega t} dt = \Omega(2\pi)^{-1} \left[\int_0^{2\pi/\Omega} T(t)\cos(n\Omega t)\, dt + i \int_0^{2\pi/\Omega} T(t)\sin(n\Omega t)\, dt \right] \qquad (B.51)$$

$$T_n = T_n^* e^{i\tau_n} \quad ;$$

T_n^* is the magnitude of T_n and τ_n is its phase as computed from Eq. (B.51). On the other hand, from Eq. (B.44) we must have

$$T_n = \hat{A}_{n1} + \hat{A}_{n2} \quad . \qquad (B.52)$$

The additional equation which is necessary to determine $\hat{A}_{n1}$ and $\hat{A}_{n2}$ is determined from the requirement that w = 0 at z = 0 for each vibrational mode. Thus,

$$r_{n1} \hat{A}_{n1} + r_{n2} \hat{A}_{n2} = 0 \quad . \qquad (B.53)$$

Solving for $\hat{A}_{n1}$ and $\hat{A}_{n2}$ from Eqs. (B.52) and (B.53), inserting the results into Eqs. (B.44) - (B.47), and then taking the real parts of the latter equations will give us the expressions for the physical meteorological quantities. First, however, it is convenient to define the following quantities in polar form.

$$\hat{A}_{n1} = -\left[r_{n2} / \left(r_{n1} - r_{n2} \right) \right] T_n = S_{n1}\, e^{is_{n1}}\, T_n = S_{n1}\, T_n^*\, e^{i\left(s_{n1} + \tau_n\right)} \quad ;$$

$$\hat{A}_{n2} = \left[r_{n1} / \left(r_{n1} - r_{n2} \right) \right] T_n = S_{n2}\, e^{is_{n2}}\, T_n = S_{n2}\, T_n^*\, e^{i\left(s_{n2} + \tau_n\right)} \quad ;$$

$$r_{n1} = M_{n1}\, e^{im_{n1}} \quad ;$$

$$r_{n2} = M_{n2}\, e^{im_{n2}} \quad ;$$

$$g_n = G_n\, e^{i\nu_n} \quad ;$$

where

$$G_n = -\, f/\left(\sigma^2 + (n\Omega)^2\right)^{1/2} \quad ,$$

and

$$\nu_n = -\tan^{-1}(n\Omega/\sigma) \quad .$$

We then have

$$\theta = \sum_{n=1}^{\infty} \theta_n \quad , \tag{B. 54}$$

$$w = \sum_{n=1}^{\infty} w_n \quad , \tag{B. 55}$$

$$u = \sum_{n=1}^{\infty} u_n \quad , \tag{B. 56}$$

$$v = \sum_{n=1}^{\infty} v_n \quad , \tag{B. 57}$$

where

$$\theta_n = \sin \lambda x\, T_n^* \Big[S_{n1}\, e^{k_{n1} z} \cos\left(n\Omega t + \ell_{n1} z + s_{n1} + \tau_n\right)$$

$$+ S_{n2}\, e^{k_{n2} z} \cos\left(n\Omega t + \ell_{m2} z + s_{n2} + \tau_n\right)\Big] \quad , \qquad \text{(B. 58)}$$

$$w_n = \sin \lambda x\, T_n^* \Big[S_{n1} M_{n1}\, e^{k_{n1} z} \cos\left(n\Omega t + \ell_{n1} z + s_{n1} + m_{n1} + \tau_n\right)$$

$$+ S_{n2} M_{n2}\, e^{k_{n2} z} \cos\left(n\Omega t + \ell_{n2} z + s_{n2} + m_{n2} + \tau_n\right)\Big] , \qquad \text{(B. 59)}$$

$$u_n = \lambda^{-1} \cos \lambda x\, T_n^* \Big[\epsilon_{n1} S_{n1} M_{n1} U_{n1}\, e^{k_{n1} z} \cos\left(n\Omega t + \ell_{n1} z + s_{n1} + m_{n1} + \eta_{n1} + \tau_n\right)$$

$$+ \epsilon_{n2} S_{n2} M_{n2} U_{n2}\, e^{k_{n2} z} \cos\left(n\Omega t + \ell_{n2} z + s_{n2} + m_{n2} + \eta_{n2} + \tau_n\right)\Big] , \qquad \text{(B. 60)}$$

$$v_n = \lambda^{-1} \cos \lambda x\, T_n^* G_n \Big[\epsilon_{n1} S_{n1} M_{n1} U_{n1}\, e^{k_{n1} z} \cos\left(n\Omega t + \ell_{n1} z + s_{n1} + m_{n1} + \eta_{n1} + \tau_n + \nu_n\right)$$

$$+ \epsilon_{n2} S_{n2} M_{n2} U_{n2}\, e^{k_{n2} z} \cos\left(n\Omega t + \ell_{n2} z + s_{n2} + m_{n2} + \eta_{n2} + \tau_n + \nu_n\right)\Big] . \qquad \text{(B. 61)}$$

In addition, the stream function $\psi = B(z, t) \cos \lambda x$ is given by

$$\psi = - \lambda^{-1} \cos \lambda x \sum_{n=1}^{\infty} T_n^* \Big[S_{n1} M_{n1}\, e^{k_{n1} z} \cos\left(n\Omega t + \ell_{n1} z + s_{n1} + m_{n1} + \tau_n\right)$$

$$+ S_{n2} M_{n2}\, e^{k_{n2} z} \cos\left(n\Omega t + \ell_{n2} z + s_{n2} + m_{n2} + \tau_n\right)\Big] . \qquad \text{(B. 62)}$$

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APPENDIX C

TOPOGRAPHIC DATA INPUT PROGRAMS TOPIN AND DATERR

Introduction

The piecewise-planar topographic description system provided for use during particle transport (see p. 37, Figure 14, and p.131 ff) requires that topographic data be prepared and stored in a specific manner on magnetic tape prior to Transport Module execution. During transport, subroutines RDTOPO and HEIGHT serve to provide the transport program with the appropriate topographic data when it is needed. Two other programs TOPIN and DATERR, have been written to aid the researcher in the preparation of topographic data tapes for DELFIC Working together, these two programs accept the user-prepared topographic description data from cards, perform many checks of data structure and consistency, and then, if the data set is adequate, prepare the input tape to be used by the Transport Module.

Description of Card Inputs

To explain the use of programs TOPIN and DATERR, we present in Table C 1 a description of the card inputs to TOPIN and DATERR (A suggested procedure for encoding actual topographic data and descriptions of the operation of both TOPIN and DATERR along with flow charts and program listings are included in the sections that follow)

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TABLE C. 1

CARD INPUTS TO TOPIN AND DATERR

Card Number	Content	Variable Names and Format
1	Limiting coordinates of the area to be covered by this topographic data tape: lower X, upper X, lower Y, upper Y (m)	TXLL, TXLU, TYLL, TYLU (4E13. 6)
2	Topography identification card	(TOPID(J)J=1, 12) (12A6)
3	Control integer to indicate which data checking program is to be used. 0 indicates DATERR, other values are unassigned	ISUBR (I 2)
4	Print control integer. 0 causes all inputs to be printed. 1 suppresses printing.	IPRNT (I 2)
5	Grid interval and limiting coordinates for the first block of topo data (m)	GRINT, BXLL, BXLU, BYLL, BYLU (5E13. 6)
6	Number of grid squares in the X direction and in the Y direction, respectively, in the regular data array S(I, J)	II, JJ (2I12)
7	Regular grid data and address array of the current data block	((S(I, J), I=1, II), J=1, JJ) (5E13. 6)
8	Subsidiary data and address array of the current data block to be read five entires per card. The end of this data set is marked by a blank entry.	SUBSID(K) to SUBSID(K+ 5) (5E13. 6)
9	Same as card set 5 but for the second data block	
10	Same as card set 6 but for the second data block	
11	Same as card 7 but for the second block	
12	Same as card 8 but for the second data block	
. . .	. . .	
Last Card	blank	

A Recommended Procedure for the Encoding of Topographic Data

The piecewise-planar description system was designed to allow the user to provide when necessary a detailed topo description for DELFIC transport. In his initial planning for describing a topo surface the user must first settle upon the limiting coordinates of the area he wishes to describe. If this rectangular area is large in relation to the desired degree of detail within it, the user may wish to break the area up into a number of subareas. It is recommended that the number of subareas be kept as small as possible, preferably one, since program running time increases with the number of subarea blocks. The procedure for encoding the data of an individual block begins with the determination of the limiting coordinates of the topo subarea corresponding to the forthcoming data block. Like the complete topographic area, all subareas are rectangular with sides arranged north-south and east-west so that only four coordinates are required to define and locate the subarea. In addition a grid interval must be specified. This interval should be arranged so that the two-dimensional array S(I, J) is used extensively because the program running time is not adversely affected by having many entries in S(I, J).

Further subdivision of the grid squares represented in S(I, J) will add to program execution time and thus should be used only when necessary to achieve the desired degree of topo detail. Of course, the data set for further subdivisions of S(I, J) is restricted by the dimensioned size of array SUBSID(K).

The procedure recommended for actually encoding the topo data for arrays S(I, J) and SUBSID(K) is as follows:

1. Secure topo sheet(s) for the area to be encoded.

2. On the topo sheet(s) draw the limits of the subarea and the grid lines to subdivide the subarea. Note that in drawing these grid lines, the user should start in the south-west corner and work toward the north-east. For a prescribed grid interval the last row and column represented on the topo sheet may, and can, extend somewhat beyond the northern and eastern limits of the subarea. An automatic compensation is made by the program to adjust the area boundaries.

3 Next. the user should consider each grid square in turn to determine whether or not further subdivision is desired. Squares not to be subdivided simply have their elevation entered in the appropriately indexed elements which, incidentally, are read by the program row by row (west to east) from south to north. Whenever the user encounters a grid square that he wishes to subdivide, an address (index K) of the first of a group of four entries in the array SUBSID(K) must be entered into S(I, J) preceded by a minus sign. The array SUBSID(K) may be blocked off into sets of four before starting this encoding procedure; if these sets are filled in sequence from the top, no difficulty will arise.

It is recommended that the researcher draw subdividing lines on the topo sheet whenever a grid square is subdivided. Grid squares are always subdivided into four equal-sized squares.

It is recommended that the user proceed in a regular manner left to right within rows and bottom to top by rows until the basic two-dimensional grid has been passed over once. The sequence of blocks-of-four in SUBSID(K) will then be established as identical to the established sequence of addresses written into S(I, J).

4. Next, the user should return to the first grid square which was marked to be subdivided and assign either heights or further addresses to its four subdivisions. The sequence in which the four subdivisions are to be treated is established by convention as indicated by the following diagram:

2	3
1	4

Note that the sequence is clockwise from the south-west corner This sequence is used by subroutine HEIGHT in retrieving height data and must be observed by the user

It is recommended that the user adopt the procedure of passing across the complete map subarea at the level of first subdivisions of grid squares before further subdividing the subdivisions In this way he will be able to maintain the required sequences without conscious effort to explicitly relate entries in SUBSID(K) to particular subdivision areas on the map

Operation of Programs TOPIN and DATERR

TOPIN

After initializing itself and rewinding two tapes TOPIN begins by reading a card containing the limiting coordinates of the complete area for which the topographic heights are to be recorded. This area must always be rectangular in form with its sides aligned in east-west, north-south directions so that four coordinates suffice to define it Next, TOPIN reads an integer (ISUBR) which indicates the user's selection of a data checking program (Currently only one data checking program, DATERR, exists) Next another integer, IPRINT, is read to indicate whether or not the program should print a full copy of its results. If IPRINT is zero, results will be printed

Next, the program branches on the value of ISUBR to a data reading and checking program Currently DATERR is the only one available so that DATERR is called at this point DATERR reads and checks topographic data for one topographic data block each time it is called DATERR returns with parameter GRINT = 0.0 when it is entered after all topographic data have been processed

Upon return from DATERR or any other data reading and checking program TOPIN checks parameter GRINT for the termination condition (GRINT = 0 0) If termination is indicated, a transfer is made to statement number 11 (see the program listing) for final processing; if otherwise, parameter ITAPE is tested to see if a valid topo tape is still possible (ITAPE = 0) or if only a check of the remaining input deck can be made (ITAPE ≠ 0) If ITAPE equals zero, a block count and the arrays S(I, J) and SUBSID(K) are put temporarily onto tape ITEMPO and a return is made to statement 81 which is just before the calls to the data checking programs. If ITAPE does not equal zero, the writing out of the processed data records is skipped. Eventually the condition, GRINT = 0. 0 will be encountered and processing will continue at statement 13. At 13 the parameter ITAPE is checked again and if errors have already been discovered in the data set, a comment is made to that effect and TOPIN stops. Otherwise, parameter ICHECK is set to 1 and DATERR is entered to carry out certain other tests on the data set as a whole. If errors are found, ITAPE is set positive so that when DATERR returns, a test of ITAPE can lead to either an error comment (if ITAPE ≠ 0) or the writing of the topography tape in final form (if ITAPE = 0) and then a final stop.

DATERR

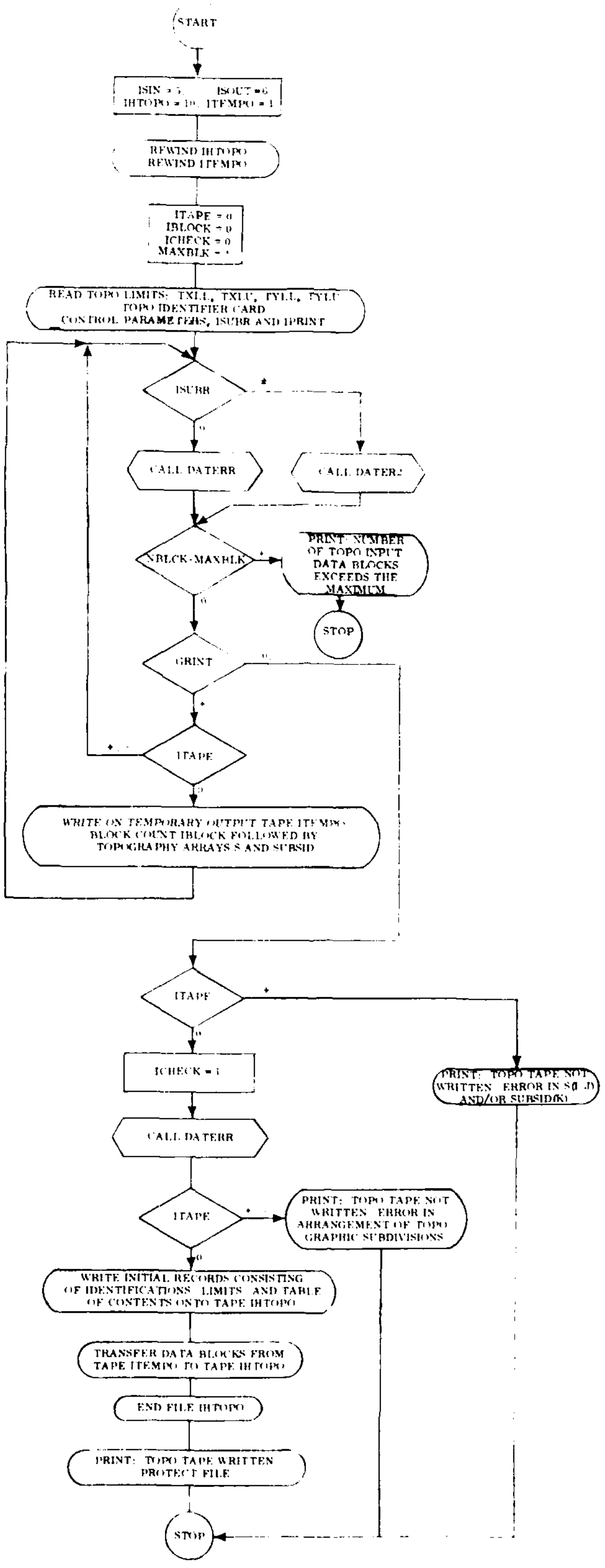
As indicated earlier this program has two different modes of operation. In the first (called when ICHECK = 0) it reads and checks a block of topographic data, and in the second (ICHECK ≠ 0) it performs tests on the complete topo table of contents and prepares the topo tape (IHTOPO) in its final form. The read-and-check mode begins at statement 16 by reading a card containing a grid interval and the limiting coordinates pertaining to the rectangular area that is to be documented in the current data block. A zero value of GRINT indicates that the last actual data block has already been processed and, therefore, if GRINT = 0. 0, a return is made immediately; if not, the block counter IBLOCK is incremented and the data arrays S(I, J) and SUBSID(K) are read. Then, at statement 22 data checking begins. Between 22 and 40 the code ascertains that the addresses imbedded with S and SUBSID are indeed reasonable and matched by appropriate values or further addresses.

Next, after 40. the highest topo height is found and recorded in the topo table of contents along with lower coordinate limits, grid interval, and maximum array indices of the current data block.

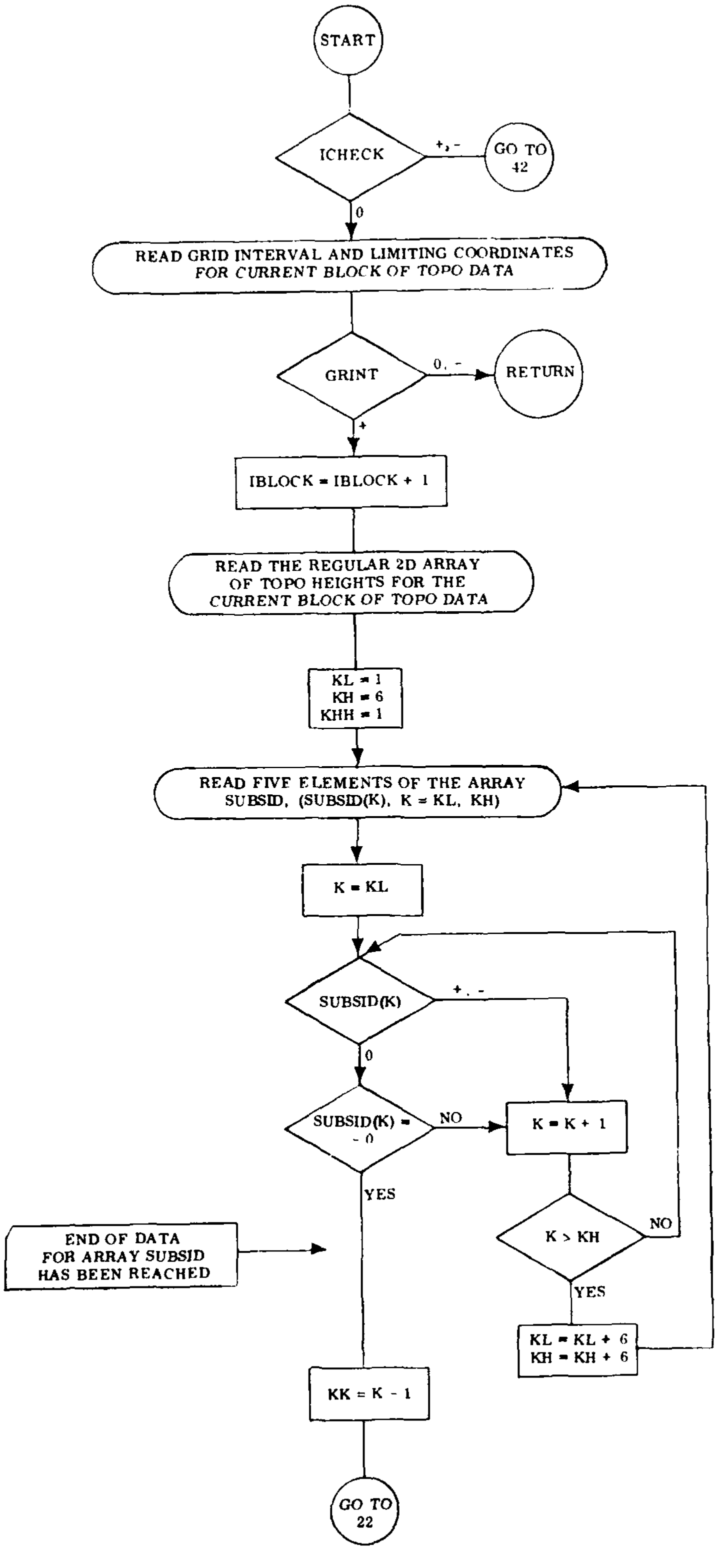
Successive tests are carried out as follows: (1) to ascertain that the number of entries in the subsidiary table is four times the total number of addresses in S(I, J) and SUBSID(K), (2) to ascertain that all height entries may be logically reached, (3) to check that the total area to be covered by the topo tape is not greater than the sum of the subareas covered by the individual data blocks, (4) to seek out any cases in which one subarea is totally included within another, and (5) to check that no gaps have been left between neighboring subareas. If any of these tests uncover an error, an explanatory comment is written and parameter ITAPE is set positive to indicate that a topo tape cannot be written in the desired final form.

Flow Charts and Program Listings

Flow charts of the main program TOPIN and subroutine DATERR are shown in FC-C.1 and FC-C.2, respectively. FORTRAN listings are included on p. 299 ff.

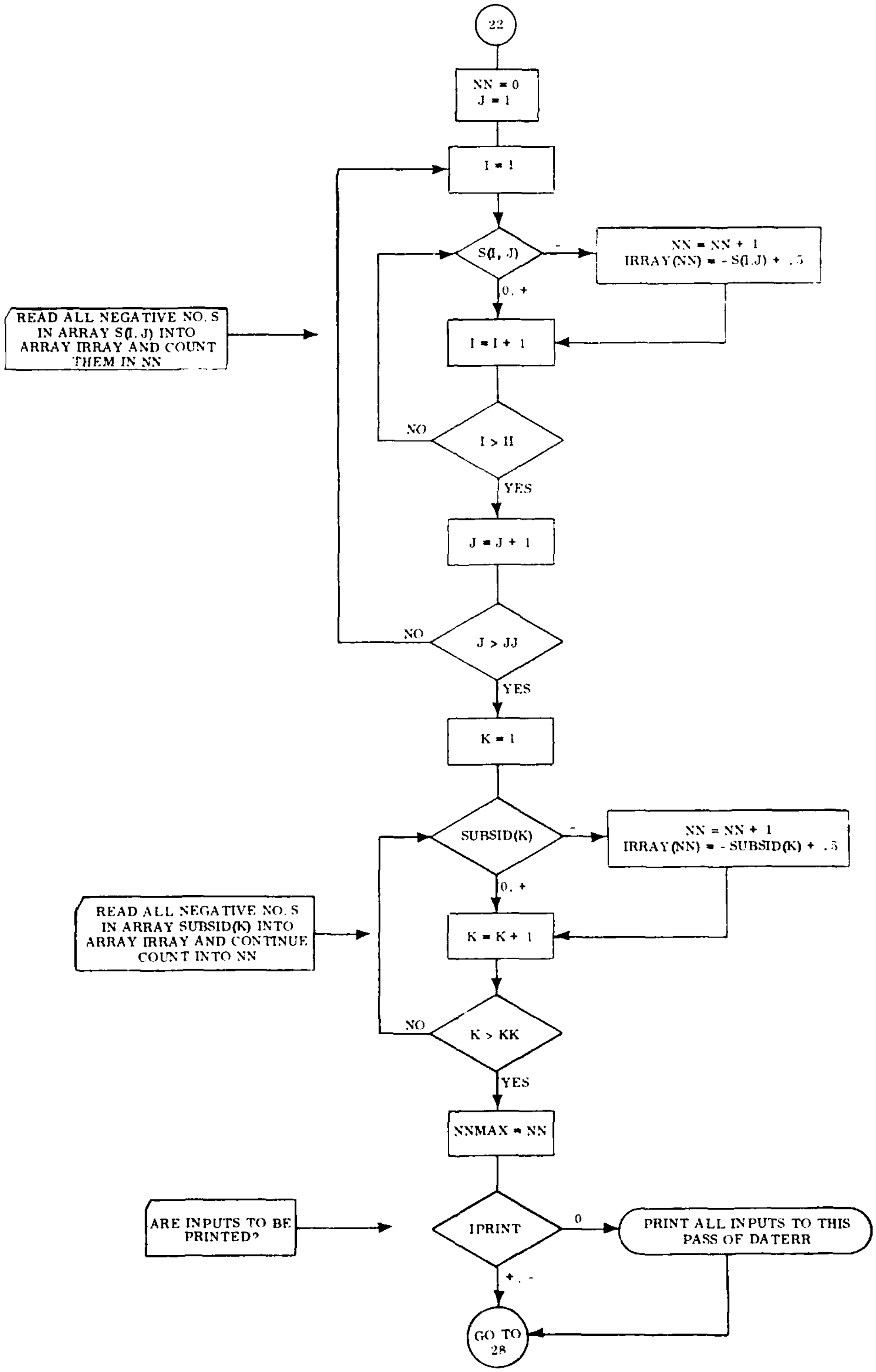

START
ISIN = 5 ISOUT = 6
IHTOPO = 10 ITEMPO = 1
REWIND IHTOPO
REWIND ITEMPO
ITAPE = 0
IBLOCK = 0
ICHECK = 0
MAXBLK = *
READ TOPO LIMITS: TXLL, TXLU, TYLL, TYLU
TOPO IDENTIFIER CARD
CONTROL PARAMETERS, ISUBR AND IPRINT
ISUBR
+
0
CALL DATERR
CALL DATER2
NBLCK-MAXBLK
+
0
PRINT: NUMBER OF TOPO INPUT DATA BLOCKS EXCEEDS THE MAXIMUM
STOP
GRINT
0
+
ITAPE
+
0
WRITE ON TEMPORARY OUTPUT TAPE ITEMPO BLOCK COUNT IBLOCK FOLLOWED BY TOPOGRAPHY ARRAYS S AND SUBSID
ITAPE
+
0
ICHECK = 1
PRINT: TOPO TAPE NOT WRITTEN ERROR IN S(I,J) AND/OR SUBSID(K)
CALL DATERR
ITAPE
+
0
PRINT: TOPO TAPE NOT WRITTEN ERROR IN ARRANGEMENT OF TOPO GRAPHIC SUBDIVISIONS
WRITE INITIAL RECORDS CONSISTING OF IDENTIFICATIONS LIMITS AND TABLE OF CONTENTS ONTO TAPE IHTOPO
TRANSFER DATA BLOCKS FROM TAPE ITEMPO TO TAPE IHTOPO
END FILE IHTOPO
PRINT: TOPO TAPE WRITTEN PROTECT FILE
STOP

FC-C.1. Flow Chart of Main Program TOPIN


START
ICHECK
+, -
GO TO 42
0
READ GRID INTERVAL AND LIMITING COORDINATES FOR CURRENT BLOCK OF TOPO DATA
GRINT
0, -
RETURN
+
IBLOCK = IBLOCK + 1
READ THE REGULAR 2D ARRAY OF TOPO HEIGHTS FOR THE CURRENT BLOCK OF TOPO DATA
KL = 1
KH = 6
KHH = 1
READ FIVE ELEMENTS OF THE ARRAY SUBSID, (SUBSID(K), K = KL, KH)
K = KL
SUBSID(K)
+, -
0
SUBSID(K) = -0
NO
K = K + 1
YES
END OF DATA FOR ARRAY SUBSID HAS BEEN REACHED
K > KH
NO
YES
KL = KL + 6
KH = KH + 6
KK = K - 1
GO TO 22

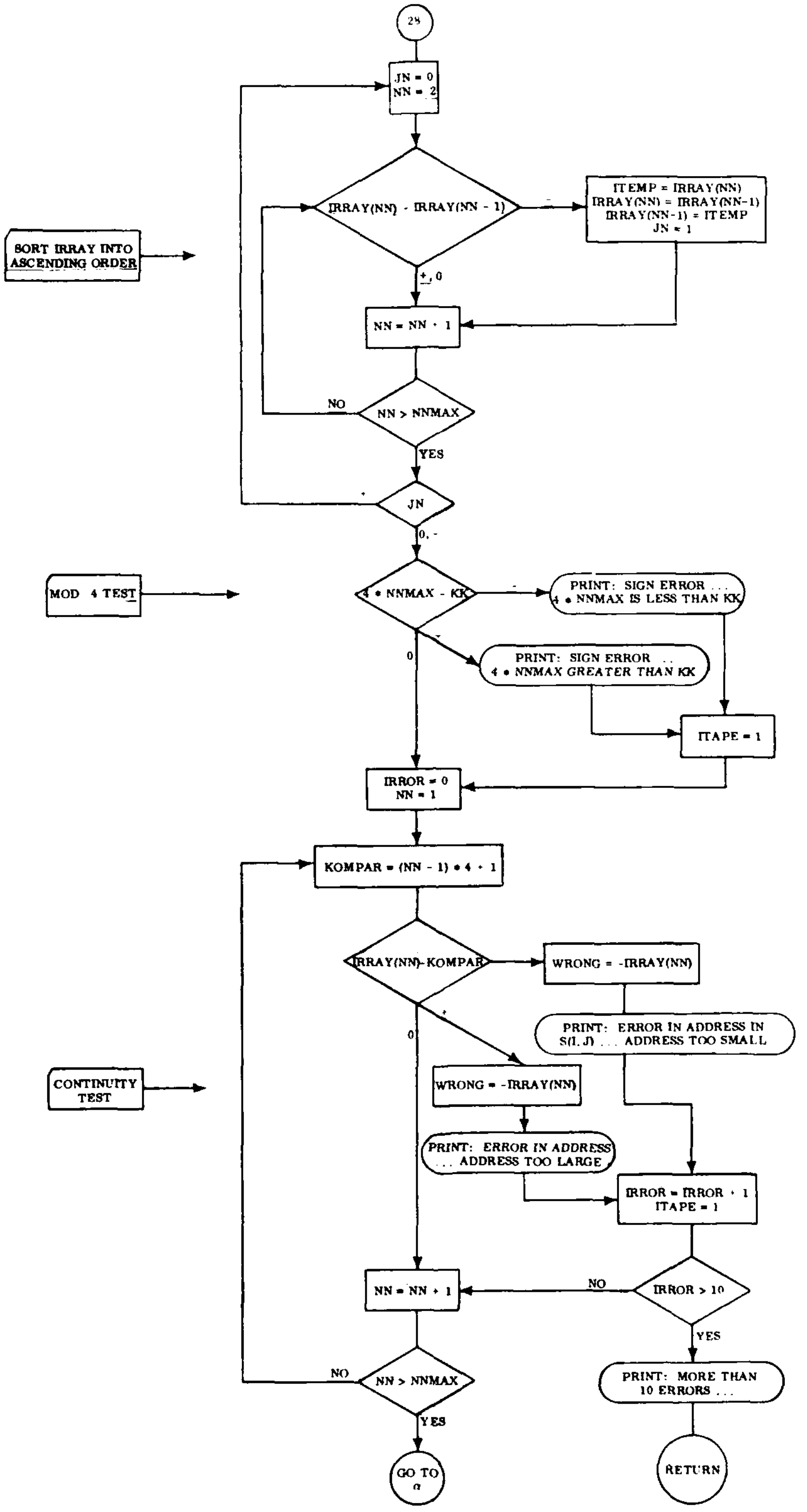
(a)

FC-C.2. Flow Charts of Subroutine DATERR


22
NN = 0
J = 1
I = 1
S(I, J)
-
NN = NN + 1
IRRAY(NN) = - S(I,J) + .5
0, +
READ ALL NEGATIVE NO.S IN ARRAY S(I, J) INTO ARRAY IRRAY AND COUNT THEM IN NN
I = I + 1
NO
I > II
YES
J = J + 1
NO
J > JJ
YES
K = 1
SUBSID(K)
-
NN = NN + 1
IRRAY(NN) = - SUBSID(K) + .5
0, +
READ ALL NEGATIVE NO.S IN ARRAY SUBSID(K) INTO ARRAY IRRAY AND CONTINUE COUNT INTO NN
K = K + 1
NO
K > KK
YES
NNMAX = NN
ARE INPUTS TO BE PRINTED?
IPRINT
0
PRINT ALL INPUTS TO THIS PASS OF DATERR
+, -
GO TO 28

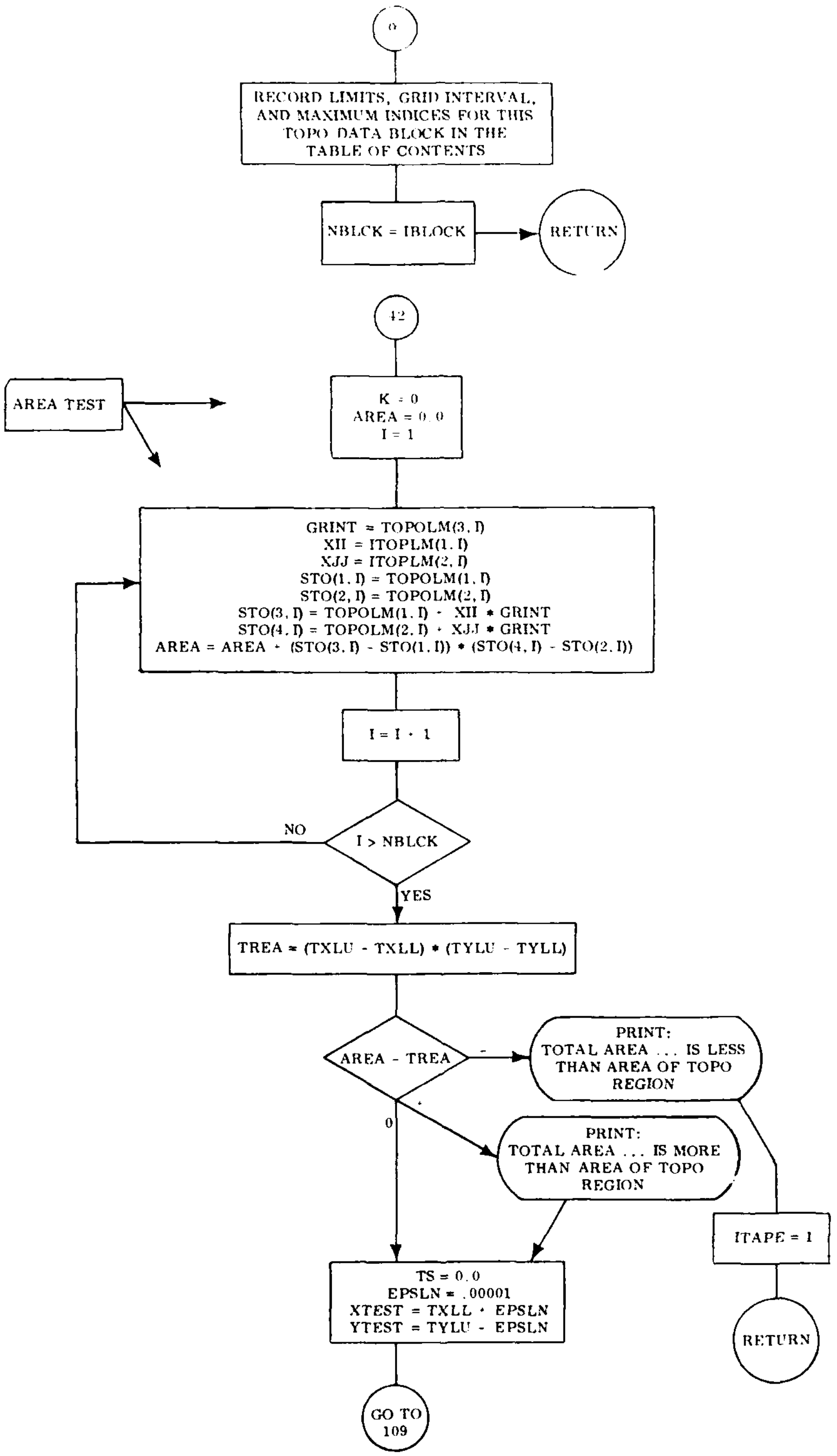
(b)

FC-C.2. (Continued) Flow Charts of Subroutine DATERR



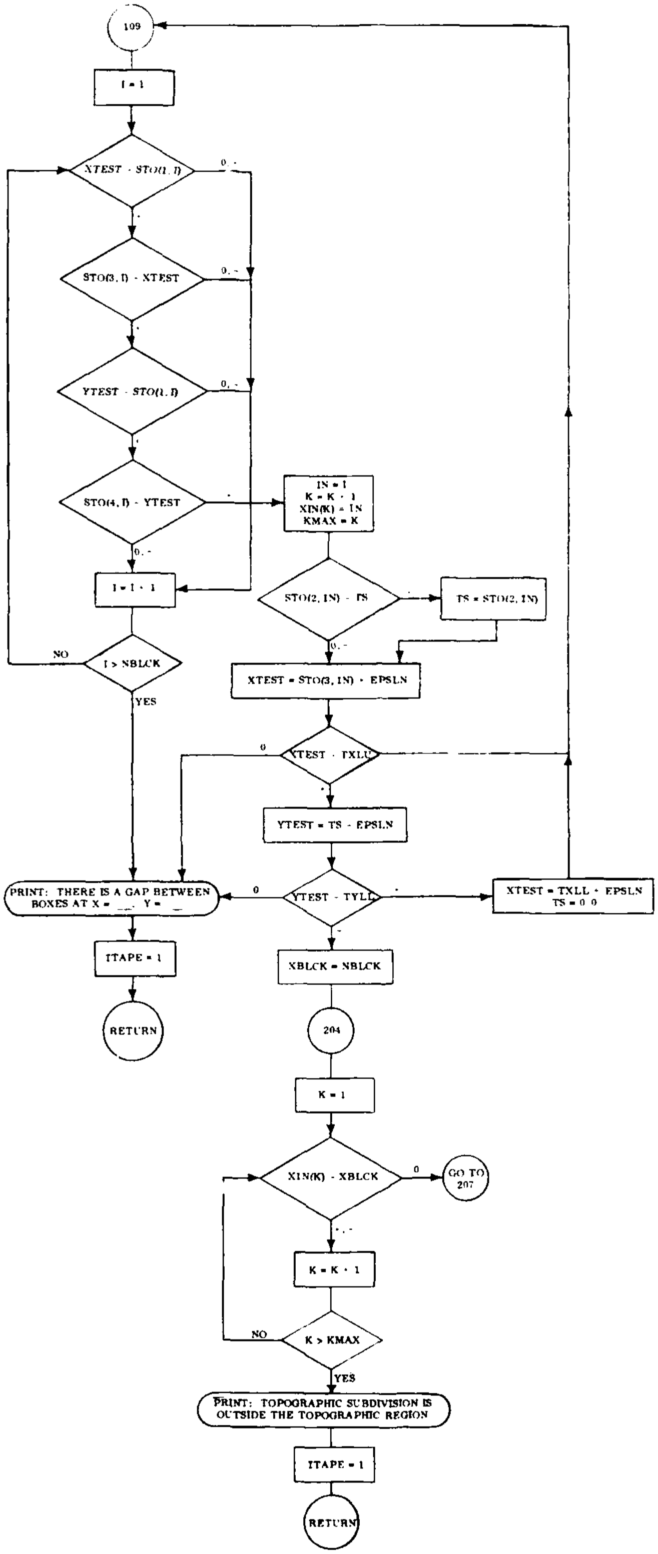
(c)

FC-C. 2. (Continued) Flow Charts of Subroutine DATERR


o
RECORD LIMITS, GRID INTERVAL, AND MAXIMUM INDICES FOR THIS TOPO DATA BLOCK IN THE TABLE OF CONTENTS
NBLCK = IBLOCK
RETURN
42
AREA TEST
K = 0
AREA = 0.0
I = 1
GRINT = TOPOLM(3, I)
XII = ITOPLM(1, I)
XJJ = ITOPLM(2, I)
STO(1, I) = TOPOLM(1, I)
STO(2, I) = TOPOLM(2, I)
STO(3, I) = TOPOLM(1, I) + XII * GRINT
STO(4, I) = TOPOLM(2, I) + XJJ * GRINT
AREA = AREA + (STO(3, I) - STO(1, I)) * (STO(4, I) - STO(2, I))
I = I + 1
NO
I > NBLCK
YES
TREA = (TXLU - TXLL) * (TYLU - TYLL)
AREA - TREA
-
PRINT: TOTAL AREA ... IS LESS THAN AREA OF TOPO REGION
0
+
PRINT: TOTAL AREA ... IS MORE THAN AREA OF TOPO REGION
ITAPE = 1
TS = 0.0
EPSLN = .00001
XTEST = TXLL + EPSLN
YTEST = TYLU - EPSLN
RETURN
GO TO 109

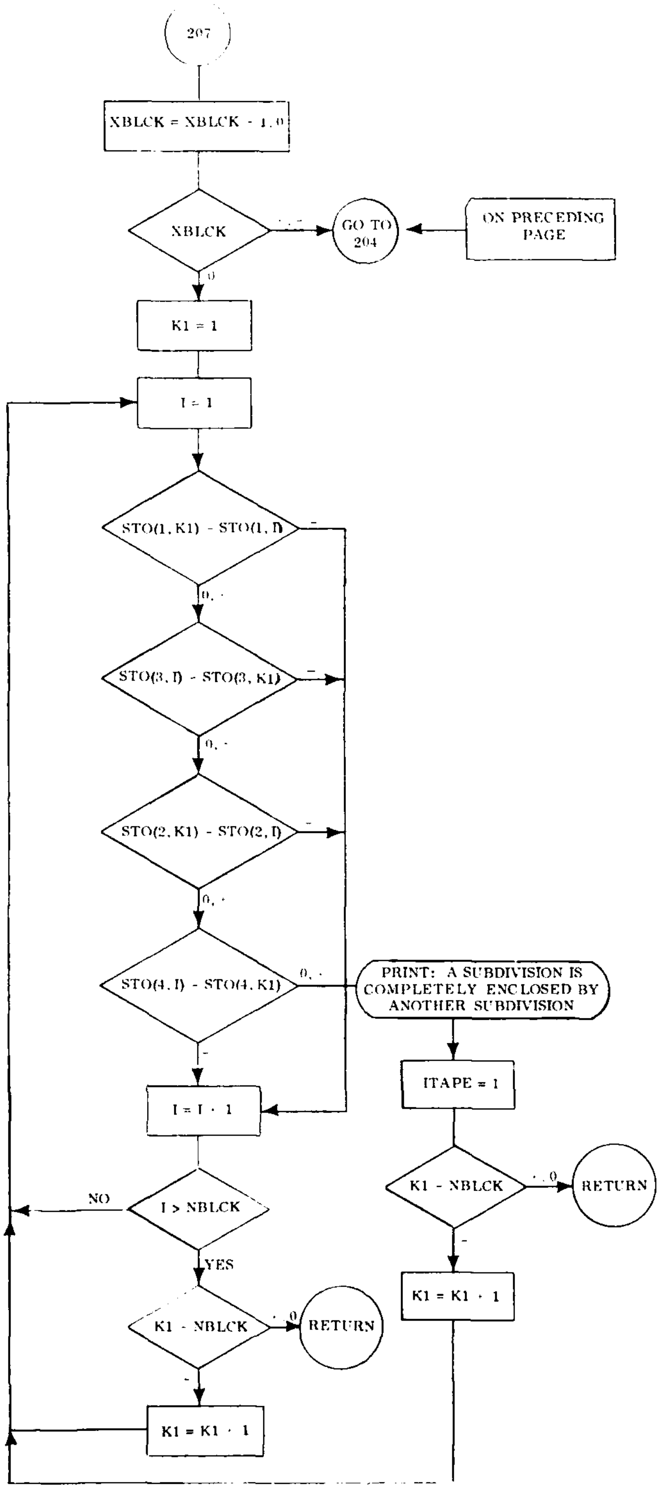
(d)

FC-C.2. (Continued) Flow Charts of Subroutine DATERR



(e)

FC-C.2. (Continued) Flow Charts ofSubroutine DATERR



(f)

FC-C. 2. (Contined) Flow Charts of Subroutine DATERR

```
$IBFTC TOPINX  LIST,DECK,M94/2                                          TOPI
C     TOPIN                                                             TOPI
C     MAIN PROGRAM FOR CONSTRUCTING TOPOGRAPHY TAPE                     TOPI
C                                                                       TOPI
C ********************    GLOSSARY FOR TOPIN AND DATERR   *************TOPI
C                                                                       TOPI
C     BXLL           LOWER X BOUNDARY OF TOPOGRAPHIC DATA BLOCK CURRENTLY TOPI
C                    IN CORE                                            TOPI
C     BXLU           UPPER X BOUNDARY OF TOPOGRAPHIC DATA BLOCK CURRENTLY TOPI
C                    IN CORE                                            TOPI
C     BYLL           LOWER Y BOUNDARY OF TOPOGRAPHIC DATA BLOCK CURRENTLY TOPI
C                    IN CORE                                            TOPI
C     BYLU           UPPER Y BOUNDARY OF TOPOGRAPHIC DATA BLOCK CURRENTLY TOPI
C                    IN CORE                                            TOPI
C     GRINT          LENGTH OF THE STANDARD GRID INTERVAL  SEE S(I,J)   TOPI
C     IHTOPO         FINAL PREPARED TOPOGRAPHY TAPE NUMBER              TOPI
C     II             UPPER LIMIT OF I DIMENSION OF S(I,J) ARRAY         TOPI
C     IPRINT         INDICATES WHETHER INPUT (TOPO ARRAYS, BOUNDARIES,  TOPI
C                    LIMITS ETC. FOR EACH BLOCK) IS TO BE PRINTED.      TOPI
C                    0 CAUSES PRINTING , 1 CAUSES NONE.                 TOPI
C     ISIN.          SYSTEM INPUT TAPE NUMBER                           TOPI
C     ISOUT          SYSTEM OUTPUT TAPE NUMBER                          TOPI
C     ISUBR          INDICATES IF = 0 THAT SUBROUTINE DATERR IS TO BE USEDTOPI
C     ITAPE          NOT ZERO INDICATES THAT ERRORS HAVE BEEN FOUND IN  TOPI
C                    THE DATA SET AND THAT A VALID TOPO TAPE CANNOT BE  TOPI
C                    WRITTEN.   A ZERO INDICATES NO ERRORS ARE APPARENT TOPI
C     ITEMPO         TEMPORARY TOPO TAPE NUMBER                         TOPI
C     JJ             UPPER LIMIT OF J DIMENSION OF S(I,J) ARRAY         TOPI
C     S(I,J)         TWO DIMENSIONAL ARRAY CONTAINING EITHER TOPOGRAPHIC TOPI
C                    HEIGHT OF GRID SQUARE I,J ON THE MAP OR A NEGATIVE TOPI
C                    NUMBER WHICH, WHEN CONVERTED TO A POSITIVE INTEGER , TOPI
C                    IS THE INDEX, K, TO A NUMBER IN THE ONE-DIMENSIONAL TOPI
C                    ARRAY, SUBSID(K).   IF A NUMBER IN S(I,J) IS NEGATIVE,TOPI
C                    IT IS CALLED THE BASE ADDRESS TO THE SQUARE OF SIDE TOPI
C                    GRINT WHOSE LOWER-LEFT CORNER IS AT LOCATION       TOPI
C                    (I-1)*GRINT , (J-1)*GRINT  ON THE MAP              TOPI
C     SUBSID(K)      ONE-DIMENSIONAL ARRAY CONTAINING EITHER A TOPOGRAPHICTOPI
C                    HEIGHT OR A NEGATIVE NUMBER WHICH, WHEN CONVERTED TO TOPI
C                    A POSITIVE INTEGER, IS THE INDEX, K, TO ANOTHER    TOPI
C                    NUMBER IN SUBSID(K), WHICH MAY IN TURN BE EITHER   TOPI
C                    A TOPOGRAPHIC HEIGHT OR ANOTHER BASE ADDRESS       TOPI
C     TXLL           LOWER X BOUNDARY OF THE COMPLETE TOPOGRAPHY AREA   TOPI
C     TXLU           UPPER X BOUNDARY OF THE COMPLETE TOPOGRAPHY AREA   TOPI
C     TYLL           LOWER Y BOUNDARY OF THE COMPLETE TOPOGRAPHY AREA   TOPI
C     TYLU           UPPER Y BOUNDARY OF THE COMPLETE TOPOGRAPHY AREA   TOPI
C                                                                       TOPI
C **********************************************************************TOPI
C                                                                       TOPI
      DIMENSION S(3 ,30),SUBSID(10000),TOPOLM(4,100),ITOPLM(3,100)      TOPI
     1 ,TOPID(12)                                                       TOPI
C                                                                       TOPI
C **********************************************************************TOPI
C                                                                       TOPI
      COMMON  GRINT   , BXLL    , BXLU    , BYLL    , BYLU    , II      TOPI
      COMMON  JJ      , KK      , S       , SUBSID  , ITAPE   , ISIN    TOPI
      COMMON  ISOUT   , IBLOCK  , IPRINT  , TOPOLM  , ITOPLM  , TXLL    TOPI
      COMMON  TXLU    , TYLL    , TYLU    , NBLCK   , ICHECK            TOPI
C                                                                       TOPI
C **********************************************************************TOPI
C                                                                       TOPI
    1 FORMAT (15H1IHTOPO    TXLL=,F6.1,8H    TXLU=,F6.1,8H    TYLL=,F6.1, TOPI
  18H    TYLO=,F6.1)
 2 FORMAT (12A6)
 3 FORMAT (I2)
 4 FORMAT (7H ISUBR=,I2)
 5 FORMAT (8H IPRINT=,I2)
 6 FORMAT (6HIHTOPO,4F6.1)
 7 FORMAT (68H TOPO TAPE NOT WRITTEN. ERROR IN S(I,J) AND/OR
  1SUBSID(K).     )
 8 FORMAT (33H TOPO TAPE WRITTEN. PROTECT FILE.)
 9 FORMAT (4E13.6)
22 FORMAT(120H TOPO TAPE NOT WRITTEN.  ERROR IN ARRANGEMENT OF TOPOGR
  1APHIC SUBDIVISIONS.                         )
33 FORMAT(120H THE NUMBER OF INPUT TOPO DATA BLOCKS EXCEEDS THE MAXI
  1UM NUMBER PERMITTED.                        )
C
C ******************************************************************
C
      DATA IDENT/6HIHTOPO/
C
C ******************************************************************
C ******************************************************************
C
      ISOUT=6
      ISIN=5
      IHTOPO=4
      ITEMPO=1
      REWIND IHTOPO
      REWIND ITEMPO
      ITAPE=0
      IBLOCK=0
      ICHECK=0
      MAXBLK=100
      READ (ISIN,9)TXLL,TXLO,TYLL,TYLO
      READ (ISIN,2) (TOPID(J),J=1,12)
      READ (ISIN,3)ISUBR
      READ (ISIN,3)IPRINT
81 IF(ISUBR)91,10,91
91 WRITE (ISOUT,6)
C
C      INSERTION POINT FOR ALTERNATE DATA CHECKING PROGRAM  DATER2
      GO TO 16
10 CALL DATERR
      IF(NBLCK-MAXBLK)30,30,31
30 IF(IPRINT)13,15,11
31 WRITE (ISOUT,33)
      GO TO 16
11 IF(ITAPE)10,12,10
12 WRITE (ITEMPO)IBLOCK
      WRITE (ITEMPO)((S(I,J),I=1,II),J=1,JJ)
      WRITE (ITEMPO)(SUBSID(K),K=1,KK)
      GO TO 81
13 IF(ITAPE)14,15,14
14 WRITE (ISOUT,7)
      GO TO 16
15 ICHECK=1
      CALL DATERR
      IF(ITAPE)21,20,21
21 WRITE (ISOUT,22)
```

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```
      GO TO 16
   20 WRITE (IHTOPO) DENTI
      WRITE (IHTOPO)IXLL,IXLU,IYLL,IYLU,NBLCK
      WRITE (IHTOPO,2)
      WRITE (IHTOPO)TOPOLM
      WRITE (IHTOPO)ITOPLM
      REWIND ITEMPO
   18 READ (ITEMPO)IBLOCK
      IM=ITOPLM(1,IBLOCK)
      JM=ITOPLM(2,IBLOCK)
      KM=ITOPLM(3,IBLOCK)
      READ (ITEMPO)((S(I,J),I=1,IM),J=1,JM)
      READ (ITEMPO)(SUBSID(K),K=1,KM)
      WRITE (IHTOPO)((S(I,J),I=1,IM),J=1,JM)
      WRITE (IHTOPO)(SUBSID(K),K=1,KM)
      IF(IBLOCK-NBLCK)18,19,19
   19 END FILE IHTOPO
      WRITE (ISOUT,8)
   16 STOP
      END
```

```
$IBFTC DATER    LIST,DECK,M94/2
C
      SUBROUTINE DATERR
C
C     SUBROUTINE TESTING FOR LOOPS AND INCORRECT ADDRESSES IN S(I,J)
C     AND SUBSID(K)
C
C ****************************************************************
C
C     SEE PROGRAM TOPIN FOR A GLOSSARY
C
C ****************************************************************
C
      DIMENSION S(3 ,30),SUBSID(10000),IRRAY(1000),ARRAY(1000),AINT(100),
     1TOPOLM(4,100),ITOPLM(5,100),STO(4,100)
C
C ****************************************************************
C
      COMMON  GRINT  , BXLL   , BXLU   , BYLL   , BYLU   , II
      COMMON  JJ     , KK     , S      , SUBSID , ITAPE  , ISIN
      COMMON  ISUBT  , IBLOCK , IPRINT , TOPOLM , ITOPLM , IALL
      COMMON  IALU   , ITLL   , ITLU   , NBLCK  , ICHECK
C
C ****************************************************************
C
    1 FORMAT (5E15.6)
    2 FORMAT (2I12)
    3 FORMAT (6F11.1)
    4 FORMAT (10H0BLOCK NO.,I7)
    5 FORMAT (9H   GRINT=,F8.1,8H   BXLL=,F8.1,8H   BXLU=,F8.1,
     18H   BYLL=,F8.1,8H   BYLU=,F8.1)
    6 FORMAT (6H   II=,I12,5H   JJ=,I12)
    7 FORMAT (25H   (S(I,J),I=1,II),J=1,JJ)
    8 FORMAT (6H   KK=,I12)
    9 FORMAT (19H   SUBSID(K),K=1,KK)
   10 FORMAT (9H   NNMAX=,I12)
   11 FORMAT (82H SIGN ERROR IN ADDRESS OR TOPOGRAPHIC HEIGHT IN S(I,J)
     1AND/OR SUBSID(K), BLOCK NO.,I7,20H .(4*NNMAX IS LESS THAN KK.))
   12 FORMAT (82H SIGN ERROR IN ADDRESS OR TOPOGRAPHIC HEIGHT IN S(I,J)
     1AND/OR SUBSID(K), BLOCK NO.,I7,23H .(4*NNMAX IS GREATER THAN KK.))
   13 FORMAT (51H ERROR IN ADDRESS IN S(I,J) OR SUBSID(K), BLOCK NO.,
     1I7,19H . WRONG ADDRESS IS,F11.1,24H . ADDRESS IS TOO SMALL.)
   14 FORMAT (51H ERROR IN ADDRESS IN S(I,J) OR SUBSID(K), BLOCK NO.,
     1I7,19H . WRONG ADDRESS IS,F11.1,24H . ADDRESS IS TOO LARGE.)
   15 FORMAT (81H ADDRESSES NOT IN INCREMENTS OF 4. MORE THAN 10 ERRORS.
     1 ERROR SEARCH IN BLOCK NO.,I7,14H DISCONTINUED.)
  220 FORMAT(120H TOTAL AREA OF TOPOGRAPHIC SUBDIVISIONS IS LESS THAN AR
     1EA OF TOPOGRAPHIC REGION.                                        )
  221 FORMAT(120H TOTAL AREA OF TOPOGRAPHIC SUBDIVISIONS IS GREATER THAN
     1 AREA OF TOPOGRAPHIC REGION. CHECK FOR OVERLAPS.                 )
  222 FORMAT(39H THERE IS A GAP BETWEEN BOXES AT XTEST=F15.9,7H YTEST=F
     115.9)
  229 FORMAT(120H A TOPOGRAPHIC SUBDIVISION IS OUTSIDE THE TOPOGRAPHIC R
     1EGION.                                                           )
  216 FORMAT(120H A SUBDIVISION IS COMPLETELY ENCLOSED BY ANOTHER SUBDIV
     1ISION.                                                           )
C
C ****************************************************************
C
      DATA QUUUCT/O1000000000000/
C
```

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```
C ***********************************************************************************
C ***********************************************************************************
C
      IF(ICHECK)42,16,42
   16 READ (ISIN,1)GRINT,BXLL,BXLU,BYLL,BYLU
      IF (GRINT) 41,41,17
   17 IBLOCK=IBLOCK+1
      READ (ISIN,2)II,JJ
      READ (ISIN,3)((S(I,J),I=1,II),J=1,JJ)
      KL=1
      KH=5
      DO 21 KHH=1,11000
      READ (ISIN,3)(SUBSID(K),K=KL,KH)
      DO 20 K=KL,KH
      IF(SUBSID(K))20,18,20
   18 A=OR(SUBSID(K),G0000CT)
      IF(A)19,20,20
   19 KK=K-1
      GO TO 22
   20 CONTINUE
      KL=KL+5
      KH=KH+5
   21 CONTINUE
C
C
C     MOD 4 CHECK
C
C
   22 NN=0
      DO 24 J=1,JJ
      DO 24 I=1,II
      IF(S(I,J))23,24,24
   23 NN=NN+1
      IRRAY(NN)=-S(I,J)+0.5
   24 CONTINUE
      DO 26 K=1,KK
      IF(SUBSID(K))25,26,26
   25 NN=NN+1
      IRRAY(NN)=-SUBSID(K)+0.5
   26 CONTINUE
      NNMAX=NN
      IF(IPRINT)28,27,28
   27 WRITE (ISOUT,4)IBLOCK
      WRITE (ISOUT,5)GRINT,BXLL,BXLU,BYLL,BYLU
      WRITE (ISOUT,6)II,JJ
      WRITE (ISOUT,7)
      WRITE (ISOUT,3)((S(I,J),I=1,II),J=1,JJ)
      WRITE (ISOUT,8)KK
      WRITE (ISOUT,9)
      WRITE (ISOUT,3)(SUBSID(K),K=1,KK)
      WRITE (ISOUT,10)NNMAX
   28 JN=0
      DO 30 NN=2,NNMAX
      IF(IRRAY(NN)-IRRAY(NN-1))29,30,30
   29 ITEMP=IRRAY(NN)
      IRRAY(NN)=IRRAY(NN-1)
      IRRAY(NN-1)=ITEMP
      JN=1
   30 CONTINUE
      IF(JN)31,31,28
   31 IF(4*NNMAX-KK)32,35,33
   32 WRITE (ISOUT,11)IBLOCK
      GC TO 34
   33 WRITE (ISOUT,12)IBLOCK
   34 ITAPF=1
   35 IRROR=0
      DO 40 NN=1,NNMAX
      KOMPAR=(NN-1)*4+1
      IF(IRRAY(NN)-KOMPAR)36,40,37
   36 WRONG=-IRRAY(NN)
      WRITE (ISOUT,13)IBLOCK,WRONG
      GO TO 38
   37 WRONG=-IRRAY(NN)
      WRITE (ISOUT,14)IBLOCK,WRONG
   38 IRROR=IRROR+1
      ITAPE=1
      IF(IRROR-10)4 ,40,39
   39 WRITE (ISOUT,15)IBLOCK
      GO TO 41
   40 CONTINUE
C
C
C     IDENTIFICATION OF LARGEST TOPO HEIGHT IN TOPO SUBDIVISION
C
C
      MM=0
      DO 240 J=1,JJ
      DO 240 I=1,II
      MM=MM+1
      ARRAY(MM)=B(I,J)
  240 CONTINUE
      DO 242 K=1,KK
      MM=MM+1
      ARRAY(MM)=SUBSID(K)
  242 CONTINUE
      MMAX=MM
  248 JM=0
      DO 245 MM=2,MMAX
      IF(ARRAY(MM)-ARRAY(MM-1))245,245,246
  246 ATEMP=ARRAY(MM)
      ARRAY(MM)=ARRAY(MM-1)
      ARRAY(MM-1)=ATEMP
      JM=1
  245 CONTINUE
      IF(JM)247,247,248
  247 TOPOLM(1,IBLOCK)=BALL
      TOPOLM(2,IBLOCK)=BTLL
      TOPOLM(3,IBLOCK)=GRINT
      TOPOLM(4,IBLOCK)=ARRAY(MMAX)
      ITOPLM(1,IBLOCK)=II
      ITOPLM(2,IBLOCK)=JJ
      ITOPLM(3,IBLOCK)=KK
      NBLCK=IBLOCK
      GO TO 41
C
C
```

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```
C     COMPARISON OF TOTAL AREA OF TOPO REGION WITH THE SUM OF THE AREAS  DATE 177
C     OF THE TOPO SUBDIVISIONS                                           DATE 178
C                                                                        DATE 179
C                                                                        DATE 180
   42 K=0                                                                DATE 181
      AREA=0.0                                                           DATE 182
      DO 100 I=1,NBLCK                                                   DATE 183
      GRINT=TOPOLM(3,I)                                                  DATE 184
      XII=ITOPLM(1,I)                                                    DATE 185
      XJJ=ITOPLM(2,I)                                                    DATE 186
      STO(1,I)=TOPOLM(1,I)                                               DATE 187
      STO(2,I)=TOPOLM(2,I)                                               DATE 188
      STO(3,I)=TOPOLM(1,I)+XII*GRINT                                     DATE 189
      STO(4,I)=TOPOLM(2,I)+XJJ*GRINT                                     DATE 190
      AREA=AREA+(STO(3,I)-STO(1,I))*(STO(4,I)-STO(2,I))                  DATE 191
  100 CONTINUE                                                           DATE 192
      TREA=(TXLO-TXLL)*(TYLO-TYLL)                                       DATE 193
      IF(AREA-TREA)200,208,201                                           DATE 194
  200 WRITE (ISOUT,220)                                                  DATE 195
      ITAPE=1                                                            DATE 196
      GO TO 41                                                           DATE 197
  201 WRITE (ISOUT,221)                                                  DATE 198
C                                                                        DATE 199
C                                                                        DATE 200
C     CHECK FOR THE ERRONEOUS ENCLOSURE OF ONE TOPO SUBDIVISION BY       DATE 201
C     ANOTHER                                                            DATE 202
C                                                                        DATE 203
C                                                                        DATE 204
  208 K1=1                                                               DATE 205
  217 DO 210 I=1,NBLCK                                                   DATE 206
      IF(I-K1)219,210,219                                                DATE 207
  219 IF(STO(1,K1)-STO(1,I))210,211,211                                  DATE 208
  211 IF(STO(3,I)-STO(3,K1))210,212,212                                  DATE 209
  212 IF(STO(2,K1)-STO(2,I))210,213,213                                  DATE 210
  213 IF(STO(4,I)-STO(4,K1))210,214,214                                  DATE 211
  210 CONTINUE                                                           DATE 212
      IF(K1-NBLCK)215,101,101                                            DATE 213
  215 K1=K1+1                                                            DATE 214
      GO TO 217                                                          DATE 215
  214 WRITE (ISOUT,216)                                                  DATE 216
      ITAPE=1                                                            DATE 217
      GO TO 41                                                           DATE 218
C                                                                        DATE 219
C                                                                        DATE 220
C     CHECK FOR GAPS BETWEEN TOPO SUBDIVISIONS                           DATE 221
C                                                                        DATE 222
C                                                                        DATE 223
  101 TS=0.0                                                             DATE 224
      EPSLN=1.0E-5                                                       DATE 225
      XTEST=TXLL+EPSLN                                                   DATE 226
      YTEST=TYLO-EPSLN                                                   DATE 227
  109 DO 105 I=1,NBLCK                                                   DATE 228
      IF(XTEST-STO(1,I))105,105,102                                      DATE 229
  102 IF(STO(3,I)-XTEST)105,105,103                                      DATE 230
  103 IF(YTEST-STO(2,I))105,105,104                                      DATE 231
  104 IF(STO(4,I)-YTEST)105,105,106                                      DATE 232
  105 CONTINUE                                                           DATE 233
      GO TO 202                                                          DATE 234
  106 IN=I
      K=K+1
      XIN(K)=IN
      KMAX=K
      IF(STO(2,IN)-TS)108,108,107
  107 TS=STO(2,IN)
  108 XTEST=STO(3,IN)+EPSLN
      IF(XTEST-TXLL)109,202,110
  110 YTEST=TS-EPSLN
      IF(YTEST-TYLL)203,202,111
  202 WRITE (ISOUT,222)XTEST,YTEST
      ITAPE=1
      GO TO 41
  111 XTEST=TXLL+EPSLN
      TS=0.0
      GO TO 109
C
C
C     CHECK TO INSURE THAT ALL TOPO SUBDIVISIONS HAVE BEEN EXAMINED
C
C
  203 XBLCK=NBLCK
  204 DO 205 K=1,KMAX
      IF(XIN(K)-XBLCK)205,207,205
  205 CONTINUE
      WRITE (ISOUT,229)
      ITAPE=1
      GO TO 41
  207 XBLCK=XBLCK-1.0
      IF(XBLCK)204,41,204
   41 RETURN
      END
```

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